

AIR FORCE**HUMAN
RESOURCES****DTIC
ELECTED
JAN 22 1990
B****TRAINING DECISIONS SYSTEM: DEVELOPMENT
OF THE RESOURCE COST SUBSYSTEM**

Frederick H. Rueter
Steven I. Feldsott

CONSAD Research Corporation
121 North Highland Avenue
Pittsburgh, Pennsylvania 15206

David S. Vaughan

McDonnell Douglas Astronautics Company
P.O. Box 516
St. Louis, Missouri 63166

**TRAINING SYSTEMS DIVISION
Brooks Air Force Base, Texas 78235-5601**

**December 1989
Interim Report for Period September 1983 - September 1988**

Approved for public release; distribution is unlimited.

LABORATORY

**AIR FORCE SYSTEMS COMMAND
BROOKS AIR FORCE BASE, TEXAS 78235-5601**

90 01 22 026

NOTICE

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely Government-related procurement, the United States Government incurs no responsibility or any obligation whatsoever. The fact that the Government may have formulated or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication, or otherwise in any manner construed, as licensing the holder, or any other person or corporation; or as conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

The Public Affairs Office has reviewed this report, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for publication.

WINSTON R. BENNETT, Program Manager
Training Decisions System Program

HENDRICK W. RUCK, Technical Advisor
Training Systems Division

HAROLD G. JENSEN, Colonel, USAF
Commander

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	December 1989	Interim -- Sep 83 to Sep 88
4. TITLE AND SUBTITLE		5. FUNDING NUMBERS
Training Decisions System: Development of the Resource Cost Subsystem		C - F33615-83-C-0028 PE - 62205F PR - 7734 TA - 12 WU - 01
6. AUTHOR(S)		8. PERFORMING ORGANIZATION REPORT NUMBER
Frederick H. Rueter Steven I. Feldsott David S. Vaughan		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)		9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
		CONRAD Research Corporation 121 North Highland Avenue Pittsburgh, Pennsylvania 15206
		10. SPONSORING / MONITORING AGENCY REPORT NUMBER
		AFHRL-TR-88-52
11. SUPPLEMENTARY NOTES		
Subcontractors with McDonnell Douglas Astronautics Company, P.O. Box 516, St. Louis, Missouri 63166.		
12a. DISTRIBUTION / AVAILABILITY STATEMENT		12b. DISTRIBUTION CODE
Approved for public release; distribution is unlimited.		
13. ABSTRACT (Maximum 200 words)		
<p>This report summarizes the research and development activities undertaken to develop and implement the Resource Cost Subsystem (RCS) of the Training Decisions System (TDS). The TDS is a computer-assisted decision aid to be used in planning the what (training content), the where (technical school, Field Training Detachment (FTD), on-the-job training (OJT)), and the when (at which point in an airman's career) of Air Force training. The TDS incorporates optimization strategies to allow training managers to ask "what if" questions related to current and possible future policy changes within the Air Force training environment. The report provides a brief conceptual overview of the interrelationships between the RCS and the three other major subsystems which compose the present TDS. The report highlights the novel approach undertaken and explicates the econometric and mathematical assumptions underlying the development of the model within this subsystem, including the cost analysis and capacity estimation capabilities which have been built into the RCS. These capabilities include methods for identifying training resource requirements, highlighting constraints that impede the provision of training at representative Air Force sites, and calculating variable costs for the provision of training for various training settings at representative sites. This report also summarizes data sources identified and the data collection activities performed and provides sample data collection instruments developed to obtain information for the RCS. In addition, the report</p>		
14. SUBJECT TERMS		15. NUMBER OF PAGES
computer-based decision aid cost models decision making		134 (5p)
military training optimal training resource cost subsystem		
16. PRICE CODE		
17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT
Unclassified	Unclassified	Unclassified
20. LIMITATION OF ABSTRACT		UL

Item 13 (Concluded):

examines implications from recent trends in Air Force personnel and training policy for training cost analysis. Finally, training resource cost and capacity issues are identified and recommendations for future RCS-related research activities and for using RCS products in the operational Air Force are proposed and discussed.

Item 14 (Concluded):

resource management
training cost model
training decisions system
training resource capacities subsystem
training resource constraints
utilization and training patterns

SUMMARY

The Training Decisions System (TDS) is a computer-based decision support technology which has been developed to provide a more integrated approach to Air Force programming and planning. The present TDS technology has been designed and developed to address the what (training content), the where (technical school, Field Training Detachment (FTD), on-the-job training (OJT)), and the when (at what point in an airman's career) of Air Force training. Further, the TDS incorporates optimization strategies to allow training managers to ask "what if" questions related to current and possible future policy changes within the Air Force training environment. The present technology consists of three major, data-based subsystems and a fourth integrating and optimization subsystem. This report provides a summary of the research activities undertaken to develop and implement the Resource Cost Subsystem (RCS) of the TDS. The RCS produces information related to the following: First, it gathers estimates of the types and quantities of resources required to provide training in different settings (technical school, field training, on-the-job); second, it gathers information regarding the availability of resources at various sites; third, it develops estimates of the capacities for various sites to support training; and fourth, it calculates the variable costs associated with providing training. The report highlights results from development and analysis activities conducted on four Air Force specialties (AFSs): Avionic Inertial and Radar Navigation Systems (328X4), Security Police/Law Enforcement (811XX), Electronic Computer and Switching Systems (305X4), and Aircraft Environmental Systems (423X1). Further, a summary of the objective data sources and data collection activities is provided along with sample data collection instruments which are necessary to develop the products of the RCS. The report also examines implications from recent trends in Air Force personnel and training policy which affect training costs analysis. Finally, training resource cost and capacity calculation issues are identified and recommendations for future RCS-related research activities and for using RCS products in the operational Air Force are discussed.



Accession For	
NTIS GRA&I <input checked="" type="checkbox"/>	
DTIC TAB <input type="checkbox"/>	
Unannounced <input type="checkbox"/>	
Justification _____	
By _____	
Distribution/ _____	
Availability Codes	
Dist	Avail and/or
	Special
A-1	

PREFACE

The Training Decisions System (TDS) is a multi-year research and development effort accomplished under Project 7734 and sponsored by HQ USAF/DPPE and HQ ATC/XPC. The goal of this effort has been to develop a computer-based decision support technology for a more integrated approach to Air Force programming and planning.

ACKNOWLEDGEMENT

Many organizations and individuals provided helpful advice and assistance during the design, development and initial implementation of the Resource Cost Subsystem (RCS) of the Training Decisions System (TDS). The number is much too large to recognize all of them individually. We greatly appreciate the support of all who participated, and especially wish to acknowledge the contributions of the following individuals:

Mr. Wayne B. Archer, Manpower and Personnel Division, Air Force Human Resources Laboratory, AFHRL/MOD, Brooks AFB, TX

Mr. Patrick Bowden, Resource Management Division, Air Training Command, HQ ATC/TTOR, Randolph AFB, TX

Dr. Burke Burright, Special Projects Office, Air Force Human Resources Laboratory, AFHRL/SA, Brooks AFB, TX

Captain Joe Filer, Test and Measurement Division, Air Force Electronic Warfare Center, AFEWC/EWT, Kelly AFB, TX

Mr. J. R. Knight, McDonnell Douglas Missile Systems Company, San Antonio, TX

Dr. Jimmy L. Mitchell, McDonnell Douglas Missile Systems Company, San Antonio, TX

Mr. D. C. Smithfield, Programs and Resources Division, Defense Training and Performance Data Center, Orlando, FL

Mr. Curtis Yelverton, Cost Analysis Directorate, Air Training Command, HQ ATC/ACC, Randolph AFB, TX

TABLE OF CONTENTS

	<u>Page</u>
1.0 INTRODUCTION	1
2.0 SUBSYSTEM OVERVIEW.	6
2.1 Purpose	6
2.2 Structure	6
3.0 ANALYTIC METHODS	10
3.1 Resource Requirements Component	10
3.1.1 Identification of Resources Required for Training	10
3.1.2 Estimation of Amounts of Resources Required for Training	11
3.1.3 Classification of Resource Requirements . .	11
3.1.4 Estimation of Resources Available for Training	12
3.1.5 Delineation of Representative Sites . . .	14
3.2 Training Capacity Component	15
3.2.1 The Ratio Method	16
3.2.2 The Mathematical Programming Method . . .	19
3.2.3 Complementary Use of the Ratio Method and the Mathematical Programming Method . .	20
3.3 Cost Estimation Component.	22
3.3.1 Measurement of Annual Recurring Expenditures	22
3.3.2 Allocation of Shared Resource Costs . . .	23
3.3.3 Development of Unit Cost Factors	27
3.3.4 Estimation of Total Variable Cost	27
4.0 IDENTIFICATION OF TYPES OF RESOURCES REQUIRED FOR TRAINING	29
5.0 ESTIMATION OF AMOUNTS OF RESOURCES REQUIRED FOR TRAINING	31
5.1 Procedure: Data Collection	31
5.2 Procedure: Data Analysis	35
5.3 Results for TDS Specialties	37
6.0 ESTIMATION OF AMOUNT OF RESOURCES AVAILABLE FOR TRAINING	42
6.1 Procedure: Data Collection	42
6.2 Procedure: Data Analysis	43
6.3 Results for TDS Specialties	46

LIST OF FIGURES

Figure		Page
1	Integrated Training Decisions System (TDS)	2
2	Integrated TDS Structure and Data Flow	3
3	RCS Structure and Data Flow	7
4	Example of Format of Resource Requirement Data Collection Instrument	33

LIST OF TABLES

Table		Page
1	Classification Framework for Resources Required for Training	13
2	Operational Unit Resource Requirements Survey Results	38
3	Distribution of Combinations of TTMs and Resource Types with One, Two, and Three or More Observations and Associated F-test Results by AFS	39
4	Distribution of R-square Values for Combinations of TTMs and Resources with Three or More Observations, by Specialty	40
5	Operational Unit Resource Availability Survey Results	47
6	Unit Travel Cost Per Mile, by Length of Trip	53
7	One-Way Airfares Used in the Estimation of Costs (in \$) for Interregional Travel	55
8	Summary of Job-Specific Salaries by AFS Based on the OSR Data Base	56
9	TTC and FTD Trainer Salaries by AFS	57
10	Comparison of Current and Alternative Air Force-Wide Training Costs (000's of \$'s): AFS 305X4	58
11	Comparison of Current and Alternative Air Force-Wide Training Costs (000's of \$'s): AFS 328X4	60
12	Comparison of Current and Alternative Air Force-Wide Training Costs (000's of \$'s): AFS 423X1	62
13	Comparison of Current and Alternative Air Force-Wide Training Costs (000's of \$'s): AFS 811XX	63
14	Costs Associated With Formal Course Training in AFS 328X4: Current U&T Pattern	65
15	Course Duration, Number of Students and Cost Per Study Week in AFS 328X4: Current U&T Pattern	66
16	Total Air Force Direct OJT Costs by Job in AFS 328X4: Current U&T Pattern	67

List of Tables (Concluded)

Table		Page
17	Estimated OJT Capacities Developed by the Ratio Method for Typical Units Characterized by a Representative Site	70
18	Estimated OJT Capacity Developed by the Mathematical Programming Method for Typical Units Characterized by a Representative Site	71
19	Estimated OJT Capacities for Typical Units Characterized by Representative Sites with Resource Shortages in AFS 328X4	74
20	Estimated OJT Capacities for Typical Units Characterized by Representative Sites with Resource Shortages in AFS 811XX	75

1.0 INTRODUCTION

The Resource/Cost Subsystem (RCS) is one of four basic subsystems of the Training Decisions System (TDS). The TDS is intended to serve as an aid for Air Force managers in making decisions about training and manpower utilization. The system is designed to assist in making such decisions as (a) who should be trained, (b) what tasks should be trained, and (c) when and where such training should be delivered within an enlisted Air Force specialty (AFS).

In addition to the RCS, the other subsystems of the TDS are: the Task Characteristics Subsystem (TCS), the Field Utilization Subsystem (FUS), and the Integration and Optimization Subsystem (IOS). The relationships among the four TDS subsystems are illustrated, at a general level, in Figure 1. As indicated in this figure, the TCS, the FUS, and the RCS are subordinate subsystems within the integrated TDS, while the IOS is the controlling subsystem which directs, coordinates, and determines optimal solutions for the other three subsystems.

Figure 2 depicts the major inputs to, outputs from, and interrelationships among the four TDS subsystems. As this figure indicates, the TDS and its subsystems obtain data from numerous sources, including: the occupational survey program (in element 1); Air Force personnel, manpower, training, and financial/accounting data files and documents (in elements 2, 4, 6, 13 and 14); and surveys and interviews of cognizant Air Force personnel (in elements 5, 7, 10, 11, 15, 18, and 19). Based on these data, the TDS subsystems apply pertinent analytic procedures (in elements 3, 12, 13, 14, 17, 20, 21, 22, 23, 24, and 25) to develop a variety of products, outputs, and results (in elements 8, 9, 12, 16, 17, 20, 21, 22, 23, 24, and 26).

The TCS generates three major products. First, it produces task training modules (TTMs) (in element 8). A TTM is a group of tasks that can efficiently be trained together.¹ Such tasks are generally performed by the same people, share common underlying skills and knowledge, involve the same equipment, and hence yield economies when they are trained as a unit. The second major output of the TCS is a compilation of the preferences of Air Force subject-matter experts (SMEs) for particular allocations of the TTMs to specific training settings (in element 20). Finally, the TCS develops estimates of the time required to provide training for particular TTMs in various

¹ The term "task training modules (TTMs)" was prescribed for such groups of tasks in the Request for Proposals for the TDS project. It has since been decided that the more concise term "task modules (TMs)" is more suitable for describing these task groups. The latter term will therefore be used in documenting all future TDS research.

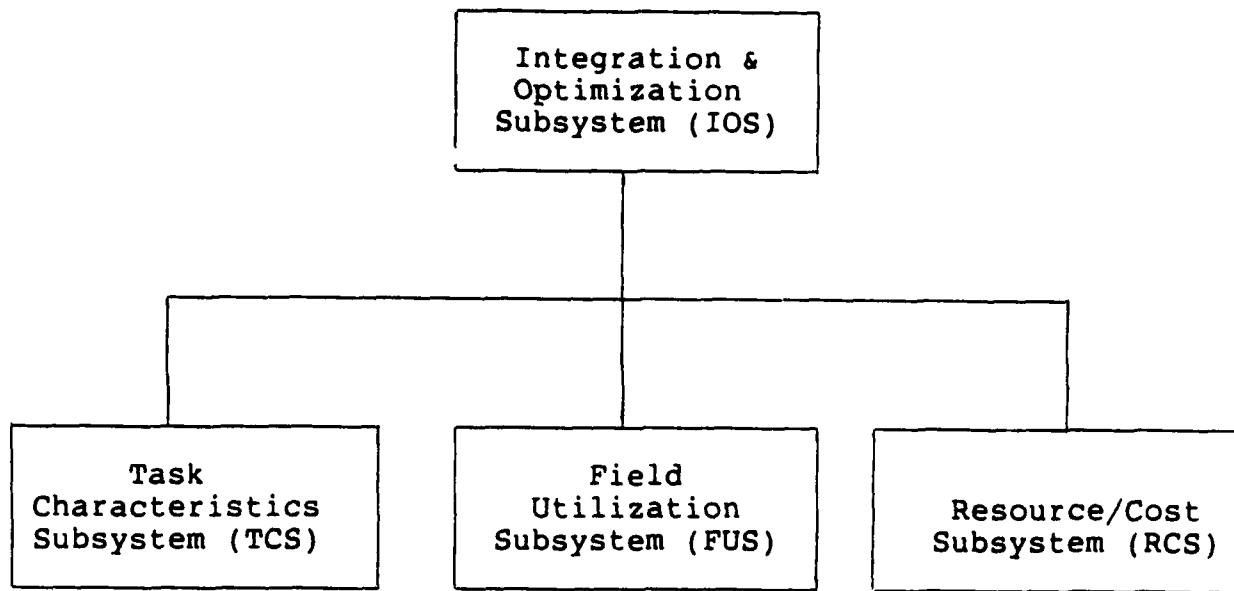


Figure 1. Integrated Training Decisions System (TDS).

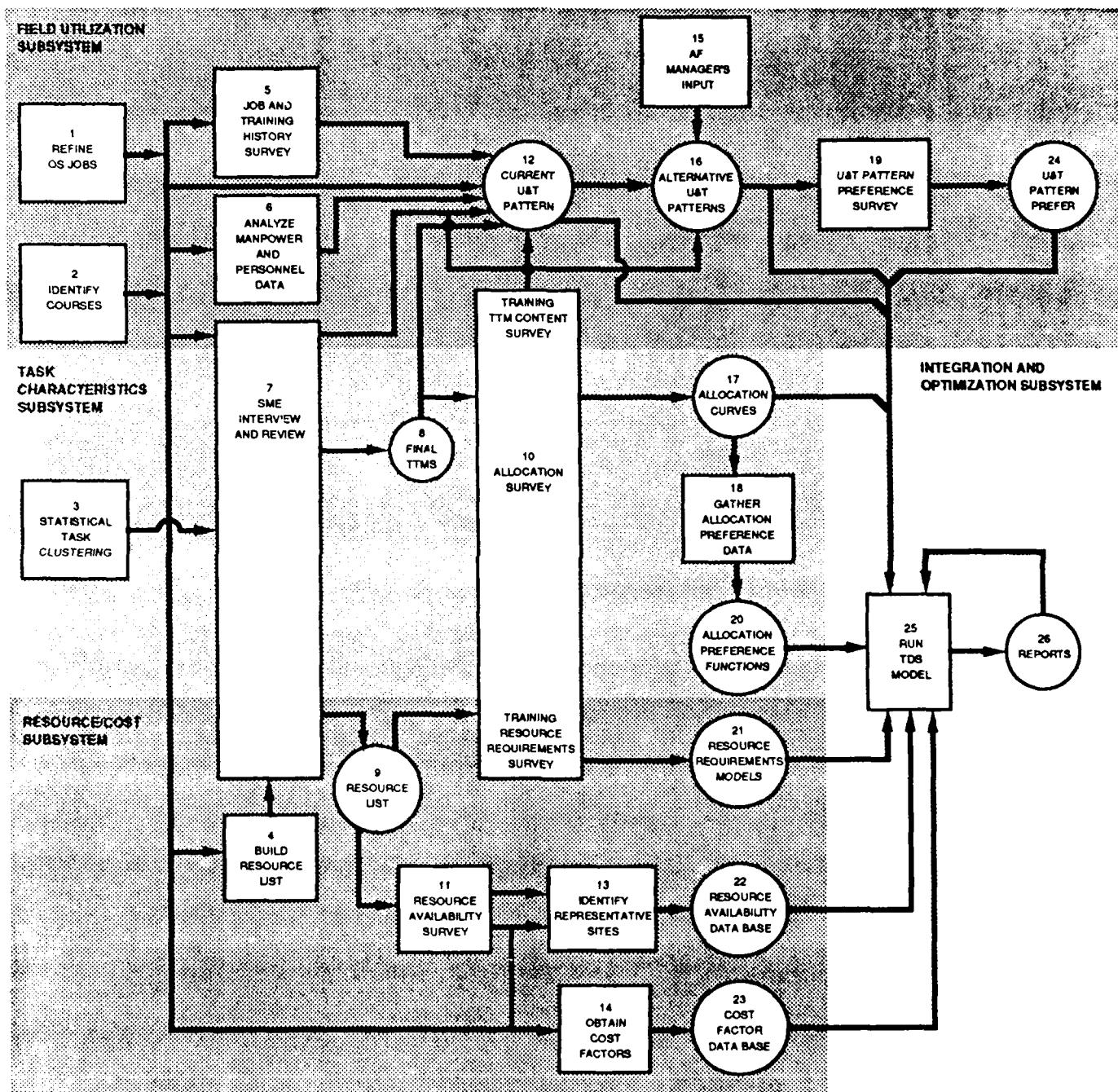


Figure 2. Integrated TDS Structure and Data Flow.

training settings, and combinations of training settings (in element 17). A training setting is a generic means of delivering training. The training settings analyzed in the TDS currently include: classroom instruction, self-paced individual study (e.g., through written materials or computer-based lessons), hands-on training, and supervised hands-on experience on the job. Classroom instruction is the main training setting used in resident technical training schools; however, courses often also involve hands-on training and self-paced individual study. The predominant training setting in Career Development Courses (CDCs) is self-paced individual study. Hands-on training is the principal setting in courses conducted by Field Training Detachments (FTDs) and Mobile Training Teams (MTTs). Supervised hands-on experience on the job is the setting used for on-the-job training (OJT). Additional training settings, such as interactive videodisc, can readily be examined in the TDS by appropriately expanding its data inputs.

The FUS generates two major products: descriptions of various utilization and training (U&T) patterns that might be applied within an AFS (in elements 12 and 16), and preferences of Air Force managers for those U&T patterns (in element 24). Descriptions are developed for the current U&T pattern in the AFS and for alternative patterns that are designed to achieve particular management objectives (in element 16). Preferences for the U&T patterns are obtained in face-to-face interviews of manpower, personnel, training, and functional managers.

Based on the outputs of the TCS and the FUS, the RCS produces four major outputs. First, it develops (a) estimates of the types and amounts of resources required to provide training in different settings (in elements 9 and 21), and (b) assessments of the availability of such resources at various sites (i.e., operational and training units) throughout the Air Force (in element 22). Then, using these data it derives (c) estimates of the capacities of representative sites (i.e., models of hypothetical Air Force units used as characterizations of several similar actual operational or training units) to accommodate specific volumes of training on particular combinations of TMs in pertinent settings (computed using analytic capabilities contained in the IOS, in element 25), and (d) estimates of the variable costs of providing that training (also computed using analytic capabilities in element 25, using data developed in element 23).

The outputs of these three TDS subsystems--the TCS, the FUS, and the RCS--are primary inputs to the IOS. The IOS combines these results to develop integrated reports for Air Force decision-makers (in element 26), and contains optimization procedures that provide analytic capabilities for deriving preferred training allocations (in element 25).

The remainder of this report focuses on the RCS. Section 2 contains an overview of the purpose of the RCS, its structure,

and its relationships with the other TDS subsystems. The three basic analytic components of the RCS, their analytic procedures, and their associated data requirements are then presented in Section 3. Sections 4 through 6, respectively, describe the methods that have been devised for collecting and synthesizing data relating to: identification of the types of resources required for the provision of training, estimation of the amounts of those resources required to support current and alternative U&T patterns, and determination of the amounts of those resources typically available for the provision of training at various actual and representative sites. The results derived in the initial applications of the data collection and synthesis methods to four AFSSs are also presented in those chapters. The AFSSs are: 305X4 (Electronic Computer and Switching Systems), 328X4 (Avionic Inertial and Radar Navigation Systems), 423X1 (Aircraft Environmental Systems), and 811XX (Security Police and Law Enforcement). The techniques developed for estimating the variable costs of providing the training required in specific U&T patterns, and the estimates computed in the initial implementation of the techniques are presented in Section 7. Similarly, Section 8 describes the techniques used to evaluate the capacity of Air Force units and higher organizational levels to provide the training needed to support particular U&T patterns, and summarizes the results obtained in the initial application of these techniques. Finally, Section 9 contains conclusions relating to the results of the analyses and the methods used to produce the results, and presents recommendations for refinement of the methods in future RCS applications.

2.0 SUBSYSTEM OVERVIEW

2.1 Purpose

The purpose of the RCS is to provide within the TDS three distinct, yet interrelated analytic capabilities:

1. Determination of the types and amounts of resources required to provide training on each TTM in each training setting, and estimation of the amounts of those resources available for use in providing training at various sites.
2. Assessment of the capacities of sites to accommodate different volumes of training on different combinations of TTMs in different training states, where a training state consists of a set of specific amounts of training conducted on specific TTMs in particular training settings.
3. Estimation of the variable costs that must be incurred in providing training on each TTM in each training setting, and in providing particular volumes of training in specific training states.

Developing a subsystem that establishes these analytic capabilities has involved: devising suitable procedures for estimating training capacities and training costs; determining the precise types of data needed to apply these procedures; assembling the necessary data for the four selected AFSs used in the TDS; developing a computer-based model to calculate the desired capacity and cost estimates using the assembled data; demonstrating the use and efficacy of the model and its associated procedures by applying the model to the data assembled for the four TDS AFSs; and, finally, conducting analysis of the sensitivity of the estimates produced by the model to the specification of values for particular parameters, such as cost factors, resource requirements, and resource availability.

2.2 Structure

Consonant with the purpose of the RCS, the subsystem contains three components: (a) the Resource Requirement Component, (b) the Training Capacity Component, and (c) the Cost Estimation Component. These components use input data from the TCS and FUS; compile resource requirements, availability and cost factor data; and interact with each other to generate capacity and cost estimates for specific U&T patterns, as depicted graphically in Figure 3.

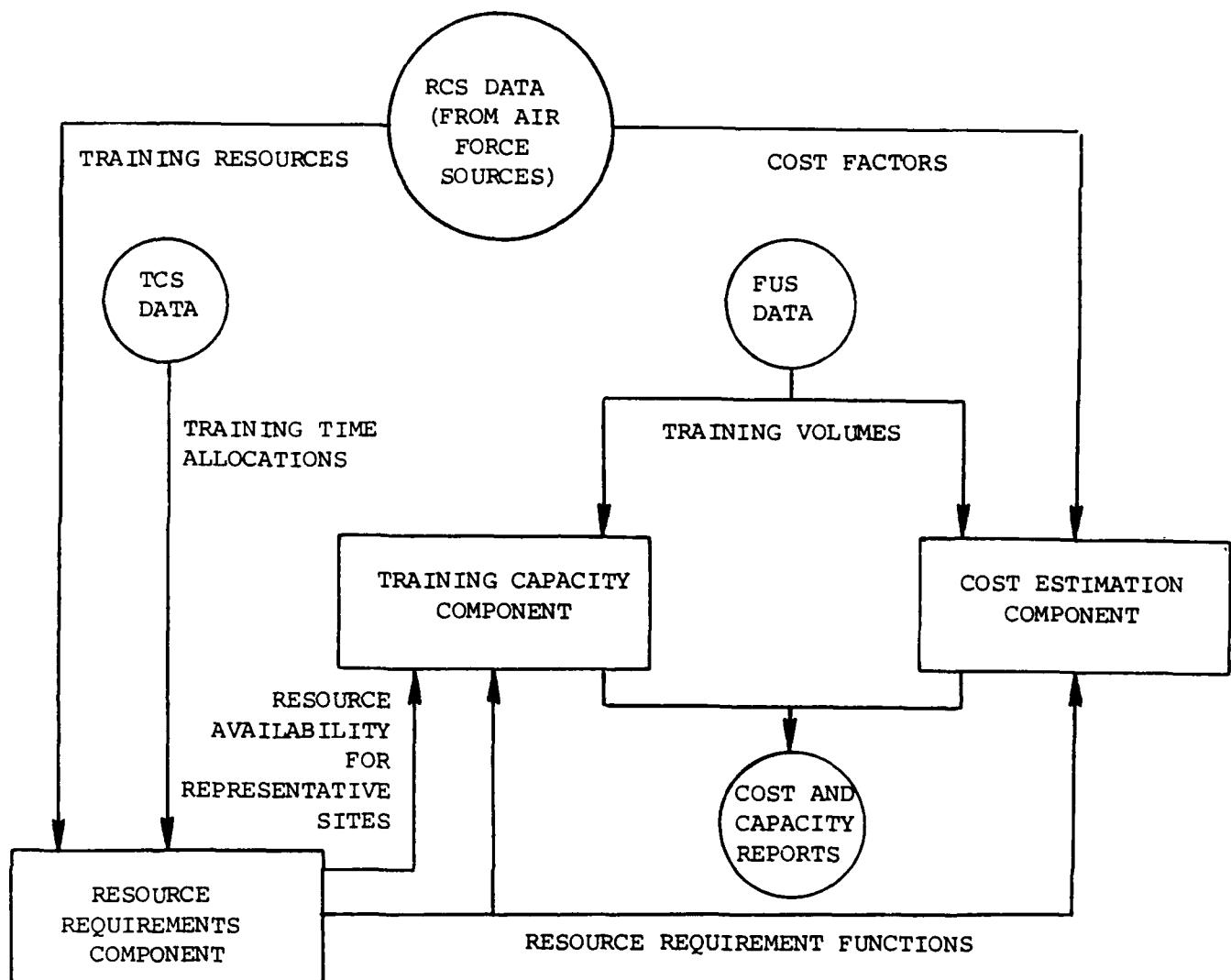


Figure 3. RCS Structure and Data Flow.

The first RCS component, the Resource Requirements Component, performs five data development functions. For each Air Force specialty, it (a) determines the specific types of resources that are required to perform training on each TTM of the specialty in each training setting, (b) estimates the quantity of each identified type of resource required for training each TTM in each setting, (c) produces compilations of these estimates classified on the basis of the ways in which the corresponding types of resources affect variable training costs and training capacities, (d) estimates the quantities of the resources available for the provision of training at various actual sites, and (e) delineates an appropriate set of representative sites for the AFS under consideration. Inputs to this component include the following: TTM definitions and amounts of time allocated for training the various TTMs in the different training settings, from the TCS; and preliminary lists of resources required for training each TTM in each setting, developed from available Air Force data in collaboration with SMEs. Based on these inputs, the component develops the basic data used in the estimation of training capacities and training costs within the other two analytic components of the RCS.

The second RCS component, the Training Capacity Component, evaluates the capacities of various representative sites to provide training in appropriate settings on different combinations of TTMs and training volumes (i.e., numbers of personnel requiring training on particular TTMs for specific amounts of time) that are compatible with the U&T patterns identified in the FUS. Inputs to this component consist of the following: training states (i.e., amounts of time allocated to training specific TTMs in specific settings to distinct groups of personnel at individual sites) and associated training volumes compatible with various U&T patterns, from the FUS; and amounts of specific resources required for training each TTM in each training setting, and availability of the resources for the provision of training at each representative site, from the Resource Requirements Component of the RCS. The component then computes estimates of the capacity of each representative site to accommodate various combinations of TTMs and training volumes, and indicates any resource limitations that constrain representative sites from accommodating the training required with particular U&T patterns.

Finally, the third RCS component, the Cost Estimation Component, computes the variable costs that would be incurred in providing training for each TTM in each training setting if all required resources were available in sufficient quantities, and then compiles the cost estimates in a form compatible with the estimates developed for training capacities. Inputs to this component include the following: estimated training resource requirements, from the Resource Requirements Component of the RCS; training states and associated training volumes compatible with various U&T patterns, from the FUS; and unit resource cost factors, such as the hourly salaries of trainees and trainers,

from external Air Force data sources. By applying the unit cost factors to the estimated training resource requirements for the specified training states and training volumes, the component estimates variable costs of conducting training in each training setting, and for each specified training volume in the corresponding training state.

A detailed discussion of the design of each of the components of the RCS is presented in the next section.

3.0 ANALYTIC METHODS

This section describes, in general terms, the methods that have been developed to implement the analytic capabilities planned for the RCS. Non-technical discussions of the analytic methods designed for each of the three components of the RCS--the Resource Requirements Component, the Training Capacity Component, and the Cost Estimation Component--are contained in Sections 3.1 through 3.3, respectively. Detailed mathematical specifications for technically complex analytic methods are presented in Appendices A and B.

3.1 Resource Requirements Component

The purpose of the Resource Requirements Component of the RCS is to collect and organize the data needed to implement the Training Capacity and Cost Estimation Components of the subsystem for specific AFSs. Accordingly, the Resource Requirements Component contains analytic procedures designed to perform five data development functions: (a) to identify the specific resources required for training each TTM in each training setting, (b) to estimate the amount of each identified resource required for training each TTM in each setting, (c) to produce compilations of those estimates classified in terms of the manner in which the corresponding resources affect annual variable training costs and training capacities, (d) to estimate the amounts of those resources available for the provision of training at various actual sites, and (e) to delineate a set of representative sites that are appropriate for the AFS under consideration. The procedures that have been devised for performing these functions are described in the remainder of this section.

3.1.1 Identification of Resources Required for Training

Both the evaluation of the capacities of various sites to provide training and the estimation of the annual variable costs of performing training require data indicating the amounts of specific resources needed for providing the training. In particular, data must be developed indicating the amounts of specific resources required for providing the training on each TTM of a specialty that is designated for each training setting within a specific U&T pattern.

To develop such data, it is first necessary to identify the various types of resources that are required for training any of the TTMs of the specialty in any training setting. Accordingly, a preliminary list of potentially relevant resources is developed on the basis of information that is routinely reported in standard Air Force documents, such as Air Training Command (ATC) Course Charts and Plans of Instruction. Whenever possible,

separate preliminary lists are compiled for the individual TTMs in the specialty.

The preliminary lists then are presented to a set of SMEs who collectively are knowledgeable about the provision of training on the various TTMs in all pertinent training settings and major commands. The SMEs review the preliminary lists and recommend revisions. For any specialty in which separate preliminary lists cannot be produced for the individual TTMs based solely on available documentation, the SMEs are asked to develop such lists based on their knowledge and experience.

Final lists are then prepared by consolidating the recommendations made by the individual SMEs. If any SME indicates that a resource is necessary for training any TTM in any training setting, that resource type is included in the final list of resources for that TTM.

3.1.2 Estimation of Amounts of Resources Required for Training

After the resources required for training each of the TTMs in a specialty have been identified, estimates of the amounts of time the resources are needed for training that TTM in particular training settings are developed. Specifically, estimates are produced indicating the amounts of time each resource is needed for providing the training on specific TTMs that is allocated to specific training settings within a particular U&T pattern.

However, because the estimates of time requirements must relate to individual TTMs and, more importantly, because the U&T patterns for which estimates must be developed include not only existing patterns but also alternative patterns that have never been implemented, it is impossible to produce the needed estimates on the basis of data that are already available. Consequently, a sample of SMEs is surveyed to obtain, for all TTMs and all training settings about which they are knowledgeable, their estimates of the amounts of time the identified resources are required for the provision of training. The SMEs are chosen to assure ample coverage of all aspects of the specialty that might involve material differences in the use of resources for the provision of training. Thus, SMEs are selected for the sample based on their practical experience with the performance of training in particular training settings, in particular major commands and, in some instances, on particular TTMs. The sample as a whole, therefore, should be capable of assessing the amounts of resources required for training any TTM of the specialty in all pertinent training settings and major commands.

3.1.3 Classification of Resource Requirements

Many different resources are required for the provision of training for any AFS in the various training settings. The

resources can include: classroom and laboratory space, time allotted to training by trainers and training supervisors, media aids, course material, school and base support resources, time devoted by trainees themselves to completing routine and remedial training, and resources expended in traveling to and from training sites.

To facilitate evaluation of both the capacities of different sites to accommodate training and the variable costs of providing training in different training states, a framework for classifying the identified types of required resources has been developed. The classification framework designates, first, whether each resource is pertinent to assessing training capacity or to estimating variable training cost. Differences between those two designations occur primarily for resources whose quantities are totally invariant in the short-term. The costs involved in acquiring such fixed resources have already been incurred and cannot be changed by modifying current levels or patterns of activity. Hence, only the costs of operating and maintaining those resources affect variable training costs; and for many fixed resources, those operating and maintenance costs (or, at least, the portion of the costs attributable to training) are negligible. Nevertheless, the resources impose limitations on training capacity. In fact, any resource can constrain training capacity throughout time periods so brief that its quantity cannot be augmented. Thus, the resources pertinent to cost estimation are essentially a subset of the resources potentially relevant for capacity evaluation.

In addition to designating the relevance of each resource to the estimation of variable training costs and training capacity, it is analytically useful to establish certain other distinctions among resources. In particular, each resource has also been classified in terms of whether individual units of the resource are used exclusively in providing training on specific TTMs or are shared with other activities. Further, for shared resources, the nature and extent of sharing have been differentiated in terms of: sharing in the training of different TTMs in the same AFS, sharing in the provision of training for different AFSs, and sharing between training and operational duties. Thus, resources have, in effect, been catalogued within the two-dimensional classification framework depicted in Table 1. Examples of specific types of resources typically included in each category within the framework are also indicated in the table.

3.1.4 Estimation of Resources Available for Training

Estimating the amounts of required resources that are actually available for providing training is reasonably straightforward, at least in concept, for courses conducted in resident technical training schools and FTDs. In those training states, virtually all resources directly involved in providing training are used exclusively for the provision of training, since training is the predominant operational responsibility of

Table 1. Classification Framework for Resources Required for Training

Resource use	Resource type	
	Variable: primarily affecting variable training costs	Fixed: affecting training capacity
Exclusive within TTM	Resident school trainee time Resident school trainer time	Media aids
Shared:		
o With training on other TTM's in same AFS	Course materials Training supervisor time Resident school support personnel time	Laboratory space Resident school support facilities
o With training on other AFSs	Training base support personnel time	Classroom space Training base support facilities
o Between training and operational duties	OJT trainee time OJT trainer time	Operational base support facilities

the training states. Thus, in those training states, estimating the amounts of resources available for providing training generally has involved merely asking experienced trainers to estimate the total quantities of those resources allotted to the courses for which they are currently serving as instructors.

In contrast, developing procedures for estimating the availability of resources required for OJT poses substantial conceptual and practical difficulties. Many of the resources required for OJT are also essential for operational duties. Thus, in essence, the resources available for performing OJT consist of the resources allocated to the operational unit that are not needed for performing operational duties. Estimating the amounts of required resources that are available for providing OJT within an operational unit, therefore, involves estimating the portion of each resource available to the unit that typically is not used in performing operational duties.

To develop such estimates for an AFS, a group of SMEs is surveyed to obtain their judgments of the amounts of time during a typical month that the various resources required for training in the specialty are actually available for providing training within the operational units to which they are assigned. The SMEs are selected to assure that estimates are requested for all operational units to which substantial numbers of airmen in the specialty are assigned.

3.1.5 Delineation of Representative Sites

Geographic considerations can affect in numerous ways the capacities of sites to perform training and the annual variable costs of conducting training. In particular, variations among sites in the availability of resources required for training, in their operational missions, and in requirements for providing training for other specialties will cause differences in the training capacities of different sites. Similarly, variations in training methods and practices among sites can entail corresponding differences in training capacities and training costs for the sites. Such differences are especially likely to exist among sites affiliated with different major commands. Furthermore, differences in travel costs between different pairs of operational units and training centers, and differences in the costs of temporary duty at different training centers, can be quantitatively important in determining the most cost-effective allocation of training among training settings and sites, particularly in relation to the fixed size of the temporary-duty (TDY)-to-schools budget in any year.

To incorporate such geographic considerations appropriately into the RCS, it is necessary to develop analytic representations of the characteristics of various sites that can be used as the basis for estimating the training capacities and variable training costs of those sites for the specialty under consideration. Interviews of SMEs conducted at Tactical Air

Command (TAC) and Strategic Air Command (SAC) headquarters have indicated that, within major commands, there are strong similarities in the availability of resources and in the manner in which training is conducted at particular sites. Specifically, within major commands, the capacity to provide training is similar for wings with the same mission, where missions are differentiated on the basis of the weapon systems, the functions (i.e., training vs. operational units), and the sizes (e.g., two-squadron vs. four-squadron) of the wings.

Accordingly, geographic considerations have been incorporated into the RCS through the delineation of several representative sites for each specialty under consideration, as described in Section 6.2. The representative sites are differentiated using standard cluster analysis and discriminant analysis techniques, based on the missions, the major commands, the availabilities of resources for the provision of training, and the job profiles associated with all operational units to which substantial numbers of airmen in the specialty have been assigned. Each representative site corresponds to several similar actual Air Force operational units, and each operational unit with a substantial number of airmen in the specialty is associated with a specific representative site.

3.2 Training Capacity Component

The purpose of the Training Capacity Component of the RCS is to derive estimates of the capacity of any site to accommodate differing volumes of training in pertinent training states, where a training state consists of a set of specific amounts of time allocated to training specific TTMs in particular training settings to a distinct group of personnel at a site. For example, a course taught in a resident technical training school represents a training state. The capacity to provide training is an attribute of an individual site, and relates to all training conducted concurrently in the training states applicable to the site. It normally does not pertain to either a portion of the training conducted at a site, or to the performance of training at several sites in combination. In general, excess capacity at one site cannot be used to augment the capacities of other sites to conduct training.

Estimation of the capacity of a site to provide training must ultimately be related to the availability of the resources required for the provision of training at that site. More specifically, such estimation involves systematically comparing the requirements for training resources with their availabilities at particular sites. Thus, to the extent that different sites receive different allotments of required resources, conduct different volumes of training, perform training on different combinations of TTMs, or contain different training settings, the

sites will have differing training capacities. Therefore, valid assessment of training capacity will require separate consideration of each distinguishable type of site.

Determination of the types and amounts of resources required for training each TTM of an AFS in each training setting, estimation of the amounts of those resources available for the provision of training at various actual sites, and delineation of a suitable set of representative sites for the AFS are accomplished within the Resource Requirements Component of the RCS, described in Section 3.1. The Training Capacity Component utilizes these data as inputs, and systematically compares the estimated resource availabilities for the representative sites to the total amounts of resources required at those sites to accommodate the specific volumes of training in particular training states designated for those sites within the U&T patterns developed by the FUS. Two basic analytic methods, the ratio method and the mathematical programming method, have been developed for performing these comparisons. Non-technical descriptions of these methods and their implementation are presented in Sections 3.2.1 and 3.2.2 below; detailed mathematical specifications for the methods appear in Appendix A. The complementary use of the two methods in evaluating training capacity is discussed in Section 3.2.3.

3.2.1 The Ratio Method

The most direct method for evaluating the capacity of a site to provide training is to compute the ratio between availability and requirements for each resource required for the provision of training at the site. More specifically, it involves computing the ratio between the total amount of each required resource that is available for the provision of training at the site and the total amount of the resource that is actually needed to provide all of the training designated for the site within a particular U&T pattern delineated in the FUS. Thus, for any resource required for the provision of training at a site, the capacity of the resource to support the training designated for the site can be evaluated mathematically, using the notation developed in Appendix A, in terms of the following ratio:

$$KR(i,s) = A(i,s)/TR(i,s)$$

where $KR(i,s)$ = the ratio between availability and requirements for resource i at site s ,

$A(i,s)$ = the total amount of resource i available for the provision of training at site s ,

and $TR(i,s)$ = the total amount of resource i required per time period for the provision of training in all training states at site s .

A calculated ratio greater than or equal to 1.0 then indicates that the available quantity of the corresponding resource is sufficient for provision of the designated amount of training, whereas a ratio less than 1.0 indicates insufficient availability of the resource. Accordingly, for provision of the designated amount of training to be unequivocally feasible, the calculated ratios for all required resources must uniformly be greater than or equal to 1.0.

However, because the ratios are based on resource use and not on output production, a calculated ratio less than 1.0 generally does not have an unambiguous relationship to the proportion of the total number of trainees at the corresponding site who can actually receive all of the training indicated for them within the corresponding U&T pattern. In particular, if there are notable differences in the total amounts of any resource required per trainee for the provision of training in different training states, the proportion of the trainees in those training states who could be accommodated by the available quantity of the resource could be substantially larger than the calculated ratio. For example, this result could be achieved by allocating the available quantity of the resource among the various training states in increasing order of the amounts of the resource required per trainee for those training states.

Nevertheless, if the total amounts of the resource required for the provision of training are sufficiently similar for the different training states in which the resource is needed at any site, the calculated ratio can reasonably be interpreted as the maximum proportion of the trainees in those training states at that site to whom the training indicated within the corresponding U&T pattern can be provided. Moreover, if this interpretation is reasonable for all resources required for training at the site, the capacity of the site to support the training indicated within that U&T pattern can also be estimated on the basis of the calculated ratios.

In particular, as described in Section 2.0 of Appendix A, both an upper bound estimate and a lower bound estimate of the capacity of the site to support that amount of training can be developed using those ratios. The upper bound estimate is based on the assumption that it is possible to concentrate all shortages of required training resources at the site on a restricted group of trainees, and the lower bound estimate is based on the assumption that it is impossible to achieve any concentration of resource shortages on particular groups of trainees.

For example, consider a hypothetical site where the capacity to perform the designated training of 10 airmen per year is impeded by shortages of two resources. The ratio between availability and requirements is 0.8 for the first resource and 0.9 for the second resource. These ratios indicate that the

available quantities of the two resources are sufficient to support the training of 8 airmen per year and 9 airmen per year, respectively. Thus, evaluated separately, the limited availability of these resources forestalls the intended training of 2 airmen per year in the case of the first resource and 1 airman per year in the case of the second resource.

The upper bound estimate is derived by assuming that it is feasible to arrange training so that the trainees to whom training cannot be provided due to limited availability of the resource that most severely restricts the attainable volume of training at the site include all of the trainees to whom training is not provided as a result of the limited availability of any other resource. Thus, in the example described above, the upper bound estimate of training capacity is 8 airmen per year, based on the assumption that use of the two resources can be arranged so that the airman to whom training is not provided due to the shortage of the second resource is one of the two airmen to whom training is not provided due to the shortage of the first resource.

The lower bound estimate, conversely, is developed by assuming that it is impossible to arrange training such that any trainee to whom training cannot be provided due to limited availability of any one resource is among the trainees to whom training is not provided as a result of the limited availability of any other resource. Thus, returning to the example, the lower bound estimate of training capacity is 7 airmen per year, based on the assumption that, regardless of how use of the two resources is allocated, the airman to whom training is not provided due to the shortage of the second resource will not correspond to either of the airmen to whom training is not provided due to the shortage of the first resource.

Furthermore, if the capacity of each site to provide the amount of training indicated within a U&T pattern can be estimated adequately on the basis of the calculated ratios between resource availabilities and resource requirements, the total capacity of the Air Force to conduct the training designated within that U&T pattern can be estimated simply by separately summing the upper bound and lower bound estimates of the training capacities of the individual sites. Similarly, if sites are delineated such that each site is associated with a single major command, the capacity of a major command to provide the training indicated within the U&T pattern can be estimated by separately summing the upper bound and lower bound estimates of the training capacities of the individual sites associated with that major command.

However, it is also important to recognize that, even if all of the conditions stated above are satisfied, the estimates described above can substantially understate the training capacities of individual sites, major commands, and the entire Air Force. This prospect exists because the estimates do not

consider the possibility that surplus resources of one type might be substituted for scarce resources of another type, at least in some TTMs at some sites. Such substitution would increase the number of trainees to whom the training indicated within a U&T pattern can be provided using the available supply of resources. Possible methods for investigating opportunities for expanding training capacity by substituting less scarce resources for more scarce resources are discussed in Section 3.2.3.

3.2.2 The Mathematical Programming Method

Mathematical programming provides a means for investigating the feasibility of allocating training resources in such a manner that the trainees to whom training is not provided as a result of the limited availability of one resource are among those to whom training is not provided due to the limited availability of other resources. To the degree that resources can be allocated to produce that outcome, the number of trainees to whom the training designated within a U&T pattern is provided will be increased.

Thus, by maximizing the degree to which any unavailability of resources is concentrated on a restricted group of trainees, the number of trainees who obtain the training indicated for them within the U&T pattern can be correspondingly maximized. Within the context of mathematical programming, this involves calculating the number of people who should be trained in each training state at each site so that the total number of people who receive their designated training is maximized and, at the same time, certain constraining conditions are satisfied. The applicable constraints include, most notably, that no training in excess of the amount designated in the U&T pattern is conducted in any training state, and that no more than the total amount of each resource available for the provision of training is used at any site.

Yet, when the limited availability of resources prevents complete provision of all specified training, merely maximizing the number of people who are trained does not take into consideration the relative importance or value to the Air Force associated with providing training to particular groups of trainees. However, if satisfactory measures of relative importance can be determined, the allocation of training resources that maximizes the total value obtained by the Air Force from the use of those resources can also be estimated through mathematical programming. Specifically, this involves calculating the number of people who should be trained in each training state at each site so that the total value accruing to the Air Force from the people who receive their designated training is maximized and, at the same time, the constraints established within the context of the maximization of the number of people trained are satisfied. In addition, either linear or nonlinear functions can be used to describe the relative value to the Air Force of providing training to different groups of trainees. Indeed, valuation functions can be expressed in forms

representing either optimizing behavior (by specifying linear or nonlinear programming formulations) or satisficing behavior (by specifying goal programming formulations).

Furthermore, additional constraints can be included in any of the mathematical programming formulations described above, whenever such constraints are appropriate for representing certain practical conditions affecting the provision of training. For example, Congress has mandated an 8-hour training day, which requires that resident technical training must be conducted for 8 full hours during each day of any course. Moreover, the substantial cost of transporting trainees to resident technical training school implies that courses taught in that setting should last some minimum number of days. These two practical conditions thus establish minimum incremental durations and minimum total durations, respectively, for courses in resident technical training schools and, as pertinent, other training settings. Mathematical representations of those conditions and any others determined to be pertinent to any training settings and any specialties can readily be incorporated as additional constraints within the appropriate portions of the corresponding mathematical programming formulations.

Detailed specifications of all of the mathematical programming formulations and constraining conditions described above are presented in Section 3.0 of Appendix A.

3.2.3 Complementary Use of the Ratio Method and the Mathematical Programming Method

In situations where the amounts of resources available for the provision of training at all sites are sufficient for conducting the training designated for those sites within a particular U&T pattern, both the ratio method and the mathematical programming method indicate the absence of any effective limitations on the capacity of the Air Force to provide training. However, neither method by itself efficiently develops all information that might be helpful in deciding how to alleviate the effective limitations on the capacity to provide training that prevail in situations where the amounts of resources available for the provision of training at one or more sites are inadequate for conducting the training allotted to those sites within a U&T pattern, while using the combinations of resources normally required for that training. Rather, the coordinated use of both methods can provide more useful information for making such decisions than either method can furnish separately.

First, for each site, the ratio method can be used to identify each type of resource for which the quantity available at the site is insufficient for conducting the training designated for the site while using the resource combinations specified within the U&T pattern. Then, it can be used to estimate the amounts by which the available quantities of those resource types are deficient for conducting the training in that manner. Third, for all other types of resources, the ratio

method can be used to estimate the surplus amounts by which the available quantities of those resource types exceed the amounts required for conducting the designated training using the specified resource combinations.

Next, for each site where the ratio method indicates that effective capacity limitations prevail, and for all resource types that the ratio method has determined are insufficiently available at that site, the mathematical programming method can be used to evaluate the maximum proportion (and, where applicable, the most valuable portion) of the total amount of training allotted to the site that can be achieved by concentrating the unavailability of resources at the site on a restricted group of trainees to the maximum degree possible. In addition, for each of those arrangements of training at the site, the mathematical programming method can be used to identify the types of resources for which the amounts available at the site impose the most severe restrictions on provision of the training designated for the site while using the resource combinations normally required for the training. Then, for each resource, the method can be used to estimate the amount by which the maximum quantity (and, where applicable, the most valuable quantity) of training achievable at the site would be increased if the amount of the resource available at the site were increased by one unit.

However, neither the ratio method nor the mathematical programming method directly provides any information about possibilities for increasing the capacities of sites to conduct training by using differing combinations of resources involving substitutions of resources with surplus amounts available for resources with inadequate supplies. With judgments from SMEs who are knowledgeable about the provision of training in pertinent training settings, the two methods can be used in combination to investigate such possibilities. In particular, based on the information derived through the ratio method concerning the types of resources with surplus or insufficient available quantities within a particular U&T pattern, SMEs can specify alternative feasible allocations of resources among TTMs and training settings that they believe are capable of providing all of the training allotted to the various sites within that U&T pattern. The ratio method and the mathematical programming method can then be applied to those alternative resource allocations, and the results of applying the two methods can be examined to determine whether any of the alternative resource allocations have eliminated or substantially reduced the initial capacity limitations. Moreover, additional applications of the foregoing analytic process can be performed, as desired, until the most satisfactory organization of training has been determined.

3.3 Cost Estimation Component

The Cost Estimation Component of the RCS has two basic purposes. The first purpose is to develop conceptually valid unit cost factors that can be combined with estimates of training resource requirements developed in the Resource Requirements Component of the RCS to produce estimates of the variable costs of providing training on each TTM of an AFS in various training settings. The second purpose is to derive estimates of the total variable cost of providing all training designated for a particular training state within a specific U&T pattern delineated in the FUS.

The costs to be estimated in this component are the annual recurring expenditures associated with using the resources actually utilized in each training setting when performing training on the various TTMs of the AFS, assuming that there is no limitation on the availability of required resources. Thus, developing the Cost Estimation Component for any specialty involves four tasks. First, the data necessary for determining the annual recurring expenditures made for each resource required for training the TTMs of that specialty in any training setting must be compiled. Next, for each resource that is not used exclusively in the provision of training on an individual TTM of the specialty in a particular setting, the portion of those annual recurring expenditures that is realistically attributable to providing training on that TTM in that setting (or, equivalently, the portion of the associated resources that is actually used in providing that training) must be estimated. Such estimation will be necessary for all resources that are either shared between training and operational duties, shared in the provision of training for different AFSs, or shared in the training of different TTMs of the same specialty. Third, appropriate unit cost factors must be derived for the various resources that affect variable training costs for any TTMs of the AFS in any training setting. Finally, procedures must be developed for estimating the total variable cost of providing the training designated for a particular training state by suitably combining the unit cost factors, the estimated number of trainees requiring training in that training state, and the training resource requirements for the TTMs and training settings corresponding to the training state.

The methods that have been devised for performing these tasks within the Cost Estimation Component of the RCS are described in the remainder of this section.

3.3.1 Measurement of Annual Recurring Expenditures

Determining the annual recurring expenditures incurred for each resource pertinent to the provision of training for any AFS in any training setting poses several notable problems. First, for some resources, standard Air Force cost compilations do not

provide data at a sufficiently detailed level for direct extraction of desired measures of annual recurring expenditures. For such resource types, it is necessary either to obtain the detailed data from which the standard cost compilations have been developed or, if the detailed data are not available and cannot be systematically retained, to apply one of the techniques for disaggregating the standard cost data that have been included within the cost estimation procedures established for the RCS, so that adequate estimates of the requisite detailed information can be produced. The conditions under which the application of those disaggregation techniques is appropriate are discussed (within the context of cost allocation in general) in Section 3.3.2.

In addition, for some resources, there are substantial geographic differentials in annual recurring expenditures. For example, the variable costs of inter-site travel and the costs of temporary duty at particular sites vary considerably among sites. For such resources, data bases have been established that accommodate cost estimation at all potentially pertinent levels of geographic detail.

3.3.2 Allocation of Shared Resource Costs

Notable conceptual difficulties complicate the determination of the portion of the total variable costs of certain resources that are required for training specific TTMs in particular AFSs and training settings. For shared resources, determining the portion of annual recurring expenditures that is attributable to the training of certain material will require the allocation of joint or common costs. Such costs arise when individual units of a resource are jointly or commonly used for both training and non-training activities, for training in different specialties, or for training on different TTMs in the same specialty. For example, certain labor and non-labor resources used in OJT are used both in training and in operational duties; in resident technical training schools, certain resources are used in providing training for several AFSs; and resources used in training administration are commonly shared among TTMs, AFSs, and training settings. Thus, training within an AFS will commonly involve costs that are not directly traceable to training or, at least, to training for individual TTMs.

The current literature on cost accounting refers to such costs as indirect costs, and distinguishes between direct and indirect costs by relating them to two types of departments typically found within organizations: departments that are directly involved in producing the organization's outputs, and departments whose primary product is service to other departments (Kaplan, 1982, pp. 353-354). Within the context of the Air Force manpower and training establishment, the organization's outputs are the provision of training on specific TTMs of specific AFSs in specific settings and the performance of operational duties; and the various types of resources that are shared in the provision of these outputs are analogous to service departments.

Whenever a valid basis can be established for allocating costs, charging the costs of a service department to the organization's outputs provides useful information for organizational resource allocation. For example, the capacity of the service department can be adjusted, in the long run, in response to the values derived using the cost allocation method. Appropriate cost allocation can also encourage managers to use resources involving lower total costs in the short run.

General guidelines for the development of methods for allocating indirect costs have been established by Horngren (1982, pp. 483-486) as follows:

1. Choose the cost objective (the independent variable) which is essentially an action. (Within the RCS, a suitable cost objective might be the provision of training on particular TTMs.)
2. Identify and accumulate the costs (the dependent variable) that relate to the cost objective.
3. Link the accumulated costs to the cost objective through the use of a suitable allocation base.

The allocation base is the means for developing a cost function that associates the total costs with the cost objective. Service department costs should be allocated among cost objectives on a basis that reflects a cause-and-effect relationship. Thus, the allocation base should be logical, it should have a high correlation with the incurrence of service department costs, and it should be easy to implement. For example, within the RCS, the cost of a trainer's time is allocated among TTMs on the basis of the proportions of the trainer's time spent providing training for the various TTMs.

The current literature on cost accounting recognizes three methods for allocating the costs of service departments. These methods are the direct method, the step or step-down method, and the reciprocal or linear algebra method.

The direct method ignores any service department costs that are incurred in providing service to other service departments. The costs of each service department would therefore be allocated directly to organizational outputs on the basis of the relative portions of departmental services rendered directly to the outputs. For example, an Air Force training supervisor might maintain training records on 80 airmen, of whom 20 have received training for two TTMs within the AFS under consideration, 40 have received training for another TTM, and 20 are receiving training in other specialties. Applying the direct method, 25% of the costs would be allocated to the first two TTMs in combination, and 50% would be allocated to the other TTM. No costs would be allocated to the other specialties. Thus, the principal

disadvantage of this method is that it ignores the effects that training in the other specialties might have on the provision of training in the specialty under consideration.

In contrast, the step or step-down method explicitly acknowledges the services that are provided by one service department to other service departments. Specifically, the method first allocates the costs of the service department that renders service to the greatest number of other service departments among the organizational outputs and the other service departments. Then, the adjusted costs of the service department that provides service to the next greatest number of other service departments (including the cost allocated to that department in the preceding step) are allocated among the organizational outputs and all remaining service departments. This process is repeated until, eventually, all service department costs have been allocated to organizational outputs. The major disadvantage of this cost allocation method is that, in larger organizations such as the Air Force, it might be extremely cumbersome to list all service departments sequentially. The method also fails to recognize any reciprocal services that might be provided among service departments.

Finally, the reciprocal or linear algebra method allocates service department costs by developing a set of equations describing the complete flow of resources among all departments, including both service departments and departments that directly produce organizational outputs. The use of computers then permits the solution of this set of simultaneous equations using linear algebra techniques. This method is the most theoretically valid approach to allocating service department costs because it recognizes reciprocal services, averts the possibility of allocating costs in the wrong sequence, and eliminates the need to determine the sequence in which service costs should be allocated.

The basic approach that has been used in allocating the costs of shared resources for the initial implementation of the RCS has involved, first, conducting interviews or surveys of knowledgeable Air Force personnel (as described in Section 3.1.2) to obtain estimates of the amounts of time that trainers, trainees, or particular types of equipment typically would be involved in training on the various TTMs. The resultant time estimates have then been used as the allocation base for assigning appropriate portions of the utilization and, for those types of resources for which satisfactory unit cost factors could be developed, the costs of the corresponding shared resources to

individual TTMs.² Which of the three allocation methods described above can fruitfully be used in this cost estimation depends critically upon the degree of detail that is incorporated in the time estimates obtained in the interviews or surveys, particularly with regard to the estimates for the time expended by trainers and training supervisors. If, as occurred in the initial implementation of the RCS, the estimates merely indicate the total amounts of time spent on training activities in general, only the direct method of cost allocation can be used. The other methods of cost allocation, however, are capable of producing much more thorough and accurate apportionments of the costs of shared resources. Accordingly, in future applications of the RCS to additional AFSs, the time estimates requested from SMEs should be designed to distinguish among differing kinds of training activity (e.g., instruction, performance monitoring, evaluation, administration). With such detailed time estimates, either the step method or the reciprocal method of cost allocation should produce more accurate and more comprehensive cost estimates; and one of those methods should be used for allocating the associated costs. The choice between the two methods should be determined on the basis of the nature of the interactions between the performance and the administration of training indicated in the collected data.

Furthermore, it is important to recognize that none of the three cost allocation methods can be applied when the costs incurred by service departments constitute joint costs. Joint costs arise, in theory, whenever the services provided by a service department are produced in fixed proportions, regardless of the relative organizational requirements for the services. More realistically, joint costs prevail in practice whenever no valid allocation base can be identified for the service provided by the department. For example, the costs of resources used in providing general support services for the entire population of an Air Force base or, more notably, the costs of resources used in providing training on fundamental principles (such as electronics principles) that constitute the conceptual basis for numerous TTMs within a specialty, would reasonably be regarded as joint costs. Under these circumstances, although it is possible to allocate costs on a systematic basis, all such allocations are arbitrary. As has been demonstrated by Thomas (1974), because of the arbitrariness of these cost allocations and the importance of using incremental costs for decision-making, allocations of joint costs should not be used as bases for resource allocation decisions. Thus, no allocations of joint costs will be included within any cost estimates developed in the Cost Estimation

² Similar use of empirical data for management accounting in private industry has been put into practice in activity-based costing systems, and is strongly advocated by several prominent accounting researchers. See, for example, Cooper and Kaplan (1988), Kaplan (1983, 1986, 1988), Klemstine and Maher (1983), Tompkins and Groves (1983), and Turney (1989).

Component of the RCS for use in decisions relating to the appropriate organization of training. Joint costs will be included only in aggregate cost estimates that embody all activities to which the joint costs relate. Such aggregate cost estimates would provide meaningful information appropriate for use in decisions relating to the size of the total budget required to support the corresponding aggregate training activities (e.g., at a site, within a major command, or for the entire Air Force).

3.3.3 Development of Unit Cost Factors

For each resource for which annual recurring expenditures are incurred as a result of the provision of training, a unit cost factor should be developed indicating the variable cost typically incurred during a year when the resource is used in the provision of training. For resources that are completely expended during the year (e.g., ordinary training materials, or the time spent on training by a trainee, a trainer, or a training supervisor), the appropriate unit cost factor is the price of the resource. For labor resources, that price corresponds to the total payment made to or on behalf of the person.

For long-lived resources such as equipment or classroom facilities, however, the appropriate unit cost factor consists of the total cost generally incurred in operating and maintaining a unit of the resource used for the provision of training throughout the year. Developing such unit cost factors usually involves either apportioning aggregate estimates of operating and maintenance costs among the various types of resources and activities to which the aggregate estimates pertain, or accumulating the estimated costs of performing the specific operations and maintenance activities typically occasioned by the use of particular types of resources in the provision of training.

3.3.4 Estimation of Total Variable Cost

In the U&T patterns developed in the FUS, the training requirements for an AFS are defined in terms of the activities that must be performed during a typical year to prepare airmen in the specialty for the various jobs to which they are assigned as they flow between jobs along the career paths generally followed in the AFS. Within this context, the amount of any resource required for the provision of training on any TTM in any training state can be adequately characterized as being directly proportional to the number of trainees receiving that training within the U&T pattern under consideration. The annual variable cost that must be incurred in providing that training therefore can be estimated merely by multiplying the required amount of each applicable resource by both the unit cost factor for the resource and the number of trainees receiving the training, and summing the resulting values over all of those resources. Moreover, the total annual variable cost of providing any more

aggregate level of training within that U&T pattern can then be calculated simply by adding together the corresponding combination of those fundamental estimates of annual variable cost. Conceptually valid estimates of the total annual variable cost of training can be developed in this manner for all training provided at an individual representative site, within a major command, or throughout the entire Air Force, for specific combinations of TTMs, for specific combinations of training states (e.g., all training states involving a particular training setting), for specific resource types or combinations of resource types, or for any combination of those alternative degrees of detail.

A detailed mathematical specification of the procedures for estimating annual variable training costs using the approach described above is presented in Appendix B.

4.0 IDENTIFICATION OF TYPES OF RESOURCES REQUIRED FOR TRAINING

In this section, the procedure used for the identification of specific resources required for the provision of training on each TTM in each AFS is described.

The first step in the process of identifying resources required for training was to obtain the Course Charts (Air Training Command (ATC) Form 449) and Plan of Instruction (ATC Form 133) for each of the Technical Training Center (TTC) courses taught in each of the four AFSs. The Course Chart includes a list of the major items of equipment needed for the course; the Plan of Instruction provides more detail, indicating the student instructional materials required for each of the units in a course block. A TTC course typically consists of several course blocks.

Using the Course Charts and Plans of Instruction in conjunction with a list of the TTMs in the AFS and the tasks included in each TTM, an attempt was made to associate specific resource items with each of the TTMs, based on similarity between one or more tasks in a TTM, and the course content description from the Plan of Instruction. This strategy proved to be reasonably successful in three of the specialties -- 328X4, 423X1 and 811XX -- and resulted in a preliminary TTM-specific list of resources required for training. In the fourth specialty, 305X4, the strategy could not be successfully implemented because establishing the relationship between the TTMs and course content descriptions proved quite difficult without a familiarity with electronic computer and switching systems.

To develop a preliminary TTM-specific list of resources for AFS 305X4, the researchers talked directly to SMEs in the career field. Given the list of TTMs and tasks associated with each TTM, and the list of test equipment from the 305X4 job inventory survey, the SMEs were able to develop a TTM-specific list of the resources required for the provision of training in their career field.

The next step in the development of the TTM-specific resource list was to develop for each AFS a booklet containing the following materials:

1. For each TTM, a list of the tasks in the TTM and the preliminary list of resources associated with the provision of training on that TTM;
2. A set of instructions briefly describing the need for the training resource data, the manner in which the preliminary lists had been developed, and specific directions as to the manner in which the SMEs were to revise the preliminary lists (see Appendix C); and

3. The list of equipment contained in the most recent job survey.

These booklets were then administered to SMEs. The additions and/or deletions made by the SMEs were then collated, and final TTM-specific resource lists were generated. The TTM-specific resource lists formed the basis of the resource requirements data collection efforts described in Section 5.0 of this report. The consolidated resource list for each of the specialties (consisting of all resources appearing in the TTM-specific resource lists) formed the basis for the resource availability data collection efforts described in Section 6.0 of this report.

5.0 ESTIMATION OF AMOUNTS OF RESOURCES REQUIRED FOR TRAINING

This section describes the procedures used for the collection of resource requirements data, the methods employed for analysis of the data, and the results that were obtained from the analysis.

5.1 Procedure: Data Collection

In developing the TCS, a sample of the airmen in each of the four AFSSs was surveyed. (See Perrin *et al.*, 1988, for a description of the sampling procedure.) The sample was drawn to include airmen who collectively were familiar with all TTMs included in their AFS based on their responses to the most recent Occupational Survey.³ These airmen were asked to provide estimates of the total amounts of time required to provide training on a specified subset of the TTMs in their specialty in specific training settings. Four training settings, corresponding to four qualitatively different modes of instruction, were considered:

1. Classroom instruction involving lecture/discussion and related reading (most resident technical training);
2. Correspondence courses; self-paced, individual study from text (all Career Development Courses (CDCs));
3. Hands-on experience in small, supervised training groups using simulators, mockups, or actual equipment (most FTDs); and
4. Hands-on experience on-the-job including observing others, practicing the tasks and receiving direction (qualification and upgrade training).

Also, the training time estimates included both current and ideal training times, which were defined as follows:

1. Current Training Time is the time you believe is currently devoted to reach minimum standards for a given group of tasks (task training module). This is for training to minimum standards only and does not mean expert or highly skilled performance. In

³ The Occupational Survey is a periodic survey of airmen in an AFS. The purpose of the survey is to determine the tasks being performed and the amount of time being spent performing those tasks by airmen in the AFS.

terms of the GO/NO GO concept, this is training up to the GO level only.

2. Ideal Training Time is the time you believe should be devoted to reach minimum standards in the most effective way. Making the most effective use of each type of training may involve providing more of some types of training and less of others. Or it may involve keeping the same levels as the current training system.

Given these training time estimates and the TTM-specific lists of resources required for training (described in Section 4.0), a data collection instrument was designed (an example of the format of the instrument for a specific TTM and setting is presented in Figure 4) such that for each TTM and training setting, the following resource-specific questions were asked:

1. The number of hours each trainee must spend working with the resource item (column B for current training, column E for ideal training);
2. If the resource item is shared, the maximum number of trainees that can effectively share the resource item simultaneously (column C for current training, column F for ideal training); and
3. If the resource item requires instructor demonstration time, the number of instructor demonstration hours required (column D for current training, column G for ideal training).

Additionally, the respondent was asked to estimate the total time typically spent by an instructor on instruction (including the time working with resources), the total time spent by an instructor on preparation/administration, and the total time typically spent by a trainee (including preparation), for training on each TTM in each training setting. All of the above questions were to be answered for both current and ideal training. Finally, if a resource was currently used, the respondents were asked to indicate the level to which training time would have to be reduced before they would stop using the resource. (Conversely, if a resource was not currently used, the respondents were requested to indicate the level to which training time would have to be increased before they would begin using the resource.)

The Training Resource Requirements Questionnaire was mailed to the airmen who had originally responded to the TTM Allocation Questionnaire. Their TTM and setting-specific training time estimates for current and ideal training from the allocation questionnaires were entered directly in their resource requirement questionnaires. Thus, the resource time estimates and other questions were to be answered within the context of the airmen's previous responses to the allocation questionnaire.

TYPE OF TRAINING: Classroom instruction involving lecture/discussion and related reading (most resident technical training)
FOR THE TYPE OF TRAINING INDICATED ABOVE AND FOR THE GROUP OF TASKS ON THE OPPOSITE PAGE, PLEASE INDICATE THE FOLLOWING RESOURCE-SPECIFIC INFORMATION:

COLUMN A	B	C	D	E	F	G	H
Resource	Number of hours each trainee must spend working with resource item.		If resource item requires instructor demonstration time, indicate number of instructor demonstration hours required.	Number of hours each trainee must spend working with resource item.	If resource item requires instructor demonstration time, indicate number of instructor demonstration hours required.	Number of hours each trainee must spend working with resource item.	If resource item requires instructor demonstration time, indicate number of instructor demonstration hours required.
Equipment							
- CTX							
- Hot Purge Kit							
- Oxygen Converter							
- Oxygen Regulator Field Tester							
- Oxygen Safety Equipment							
- Sonic Leak Detector							
- Oxygen System Leakage Testers							
- Trainer 1875490 Liquid Oxygen System							
- TTU/162E Converter Tester							
- Test Sets, Oxygen							
- Oxygen Connection Testers							
- Oxygen Drain Kits							
						Current Training	Ideal Training
						Total Instructor time for:	
						Instruction (including time working with resources)	_____
						Preparation/Administration (if known)	_____
						Total trainee time (including preparation)	_____

Figure 4. Example of Format of Resource Requirement Data Collection Instrument.

In addition to the above described survey of training resource requirements in general, it was also necessary to collect similar information concerning training resource requirements in individual TTC and FTD courses in each of the specialties⁴. As there had been no previous data collection efforts for the TDS in this area, it was necessary to design a data collection package that would meet the data needs of both the FUS and RCS. For the FUS, it was necessary to establish a mapping between TTMs and courses and, for each TTM in a course, to estimate the amount of time devoted to that TTM in each of three training settings -- classroom instruction, supervised hands-on training, and self-paced individual study. For the RCS, given the TTMs in a course and the training times associated with each of the three training settings, it was necessary to obtain estimates of the amounts of time that specific resources are required for training each of the TTMs in each of the settings.

To obtain the course-specific data required for the two subsystems, a packet consisting of four booklets was designed:

1. Training Time Questionnaire
2. Task Training Module (TTM) Reference Volume
3. Training Resource Requirements Questionnaire
4. Resource Availability Questionnaire

The Training Time Questionnaire, used in conjunction with the TTM Reference Volume, was designed to meet the data needs of the FUS. The Training Resource Requirements Questionnaire was identical in format to the data collection instrument shown in Figure 4. However, instead of addressing a specified subset of TTMs, all TTMs were included, and the respondents were directed to provide estimates only for the TTMs and training settings associated with their courses. The design and purpose of the fourth booklet, the Resource Availability Questionnaire, are described in Section 7.0.

In AFSS 328X4 and 423X1, these four-booklet packets were mailed to the FTD commanding officer, with instructions to distribute the packets to the FTD course instructors. All TTC data collection and AFS 305X4 FTD course data collection were done on a face-to-face basis by Air Force Human Resources Laboratory (AFHRL) and/or contractor research personnel.

⁴ The Security Police Career Field has no FTD-type courses.

5.2 Procedure: Data Analysis

One of the purposes of the RCS is to allow Air Force Training Managers to examine the cost and capacity consequences of possible restructurings of training. To establish a quantitative basis for evaluating these consequences, it was necessary to derive estimates of the statistical relationships between the time allocated for training on each of the TTMs in each of the training settings, and the amounts of resources required for the provision of that training.

Thus, within the data base compiled through the data collection efforts described in the previous section, each estimate of the time allocated, currently or ideally, for providing training on a particular TTM in a particular training setting was associated or paired with a number of resource requirement estimates including:

1. the number of hours that a trainee must spend working with each type of equipment, weapon, or facility (e.g., firing range) during that training;
2. the number of hours that a trainer must spend in demonstrating the proper use of each type of equipment, weapon or facility in that training;
3. the total number of hours that a trainer must spend performing the instruction associated with that training;
4. the total number of hours that a trainer must spend on preparation and administration of that training; and
5. the total number of hours that a trainee must spend obtaining that training, including preparation time.

Each of these pairs of values represents a data point, $[T(j,k,m), R(i,j,k,m)]$, where: $T(j,k,m)$ = the estimated time allocated for training on TTM j in training setting k in allocation m ; $R(i,j,k,m)$ is the estimated number of hours that resource i is required for the provision of training on TTM j in training setting k in allocation m ; and allocation m is a current or ideal allocation specified by some SME. Then, for each TTM/training setting combination and each of the various types of resource requirement estimates listed above, a relationship of the form

$$R(i,j,k,m) = \alpha(i,j,k) + \beta(i,j,k) \cdot T(j,k,m)$$

was statistically estimated where $\alpha(i,j,k)$ and $\beta(i,j,k)$ were the least square linear regression estimators of the coefficients of the relationship indicating requirements for resource i in providing training on TTM j in training setting k .

If only a single observation, $[T(j,k,m), R(i,j,k,m)]$, was available for a particular TTM, setting and resource combination, then the relationship was assumed to have the form

$$R(i,j,k,m) = \beta(i,j,k) \cdot T(j,k,m)$$

and hence

$$\beta(i,j,k) = R(i,j,k,m)/T(i,k,m).$$

That is, the relationship was estimated as a straight line between the single data point and the origin.

Thus, given an estimate of the time allocated for providing training on a particular TTM in a particular training setting, and using the estimated linear relationships described above, the RCS calculates the total amount of time that trainers, trainees, and each of the resources required for the provision of training on that TTM in that training setting would be needed with that training time allocation. In estimating time requirements for trainers, and for non-personnel resources used in demonstrations performed by trainers, assumptions regarding normal trainee/trainer ratios in the various training states were required. After discussions with personnel familiar with Air Force training, the following trainee/trainer ratios were adopted for AFSs 305X4, 328X4, and 423X1:

1. For TTC courses, where the typical class size was judged to be between 15 and 20, the ratio 17.5:1 was assumed;
2. For FTD courses, where the typical class size was judged to be between 8 and 10, the assumed ratio was 9:1; and
3. For OJT, the ratio 1.5:1 was used in the analysis.

In AFS 811XX, the trainee/trainer ratios adopted were as follows:

1. For TTC courses involving dogs, the ratio 16:1 was assumed;
2. For other TTC courses, the assumed ratio was 40:1; and
3. For OJT, the ratio 6:1 was used in the analysis.

5.3 Results for TDS Specialties

In this section, the results of the data collection and analysis efforts undertaken to enable estimation of the amounts of resources required for the provision of training are presented.

Across the four AFSs, a total of 518 Training Resource Requirements Questionnaires were mailed to airmen at operational units who had previously responded to the TTM Allocation Questionnaire as part of the development of the TCS (see Appendix D, Section 1.0). Two hundred thirty-eight Resource Requirements Questionnaires with usable responses were returned, resulting in a response rate of 45.9%. Time and resource limitations precluded extensive follow-up efforts to increase the response rate. AFS 328X4 had the best response rate (63.7%), while the other three AFSs had response rates averaging slightly less than 41%. These results are summarized in Table 2.

In addition to the resource requirements data collected from operational units, resource requirements data collection efforts were also undertaken for FTD and TTC courses as described in Section 5.1 (see also Appendix D, Section 2.0). These efforts resulted in the following data:

1. In AFS 305X4, resource requirements data were obtained for 12 FTD courses and 23 TTC courses;
2. In AFS 328X4, resource requirements data were obtained for 15 FTD courses and 2 TTC courses;
3. In AFS 423X1, resource requirements data were obtained for 7 FTD courses and 1 TTC course; and
4. In AFS 811XX, resource requirements data were obtained for 22 TTC courses.

After computer-readable resource requirements data files were created, coefficient values and associated interpretive statistics were estimated for the linear relationships described in Section 5.3. Results of these efforts are summarized in Tables 3 and 4.

Table 3 shows the number of combinations of TTMs and resource types for which one, two, and three or more observations were obtained for each AFS. In addition, where three or more observations were provided, the table indicates the number of estimated relationships that were statistically significant at both the $p<0.05$ and the $p<0.01$ levels. Across the four AFSs, 35.6% of the TTM, training setting and resource type combinations had only one or two observations. For the remaining combinations with three or more observations where regression equations could be estimated, 55.6% of those estimated relationships were significant at the $p<0.05$ level.

Table 2. Operational Unit Resource Requirements Survey Results

	Specialty				
	305X4	328X4	423X1	811XX	Total
Number Mailed	144	113	112	149	518
Number Returned	60	72	44	62	238
Response Rate	41.7%	63.7%	39.3%	41.6%	45.9%

Table 3. Distribution of Combinations of TTM's and Resource Types with One, Two, and Three or More Observations and Associated F-test Results by AFS

	<u>305X4</u>	<u>328X4</u>	<u>423X1</u>	<u>811XX</u>	<u>Total</u>
Number (Percent) of TTM/Resource Combinations with 3 or More Observations	2,751 (54.7)	1,946 (56.2)	1,936 (76.0)	5,106 (71.0)	11,739 (64.4)
F-test: Percent Statistically Significant at:					
$p < 0.01$	33.7	45.2	41.9	30.3	35.5
$p < 0.05$	52.3	66.0	63.2	50.6	55.6
Number (Percent) of TTM/Resource Combinations with Two Observations	1,029 (20.5)	702 (20.3)	280 (11.0)	1,136 (15.8)	3,147 (17.3)
Number (Percent) of TTM/Resource Combinations with One Observation	1,245 (24.8)	815 (23.5)	332 (13.0)	949 (13.2)	3,341 (18.3)
Total Number of TTM/Resource Combinations	5,025	3,463	2,548	7,191	18,227

**Table 4. Distribution of R-square Values for Combinations of
TMs and Resources with Three or More Observations,
by Specialty**

Range of R-square values	Specialty									
	305X4		328X4		423X1		811XX		Total	
	N ^a	Pr ^b								
0.0 \leq R ² \leq 0.1	758	1.000	425	1.000	518	1.000	1,350	1.000	3,051	1.000
0.1 \leq R ² \leq 0.2	292	0.724	158	0.782	180	0.732	654	0.736	1,284	0.740
0.2 \leq R ² \leq 0.3	228	0.618	157	0.700	154	0.639	408	0.608	947	0.631
0.3 \leq R ² \leq 0.4	215	0.535	121	0.620	167	0.560	412	0.528	915	0.550
0.4 \leq R ² \leq 0.5	158	0.457	118	0.558	107	0.474	274	0.447	657	0.472
0.5 \leq R ² \leq 0.6	144	0.400	122	0.497	92	0.418	270	0.393	628	0.416
0.6 \leq R ² \leq 0.7	159	0.348	118	0.434	120	0.371	322	0.340	719	0.363
0.7 \leq R ² \leq 0.8	147	0.290	172	0.374	101	0.309	291	0.277	711	0.301
0.8 \leq R ² \leq 0.9	169	0.236	173	0.285	136	0.257	378	0.220	856	0.241
0.9 \leq R ² \leq 1.0	481	0.175	382	0.196	361	0.186	747	0.146	1,971	0.168
Total	2,751		1,946		1,936		5,106		11,739	

^a Number of estimated regression equations with R-square values within the designated range.

^b Proportion of estimated regression equations with R-squares within or above the designated range.

Table 4 displays the distribution of R-square values computed for the regression equations estimated for each of the four AFSs. The R-square statistic measures the fraction of the variance around the mean of the dependent variable (i.e., a resource-specific time estimate) that is accounted for collectively by all of the explanatory variables included in the regression equation. R-square can be used as a measure of the "goodness of fit" of the model; the closer the R-square value is to 1.0, the better the model fits the data (particularly in comparison to the alternative of using the mean to characterize the data). Across the AFSs, 41.6% of the R-square values exceeded 0.5, and nearly 17% were greater than 0.9. Of the four AFSs, AFS 328X4 exhibited the best results, with almost one-half of the R-square values exceeding 0.5. The lowest R-square values were obtained for AFS 811XX, where slightly less than 40% of the R-square values exceeded 0.5. More detailed results are presented in Rueter et al. (1988a, 1988b, 1988c, 1988d).

6.0 ESTIMATION OF AMOUNT OF RESOURCES AVAILABLE FOR TRAINING

The amount of training that can be performed at any site is directly related to the availability of the resources that are required for the provision of that training. It is therefore necessary to collect data on the availability of resources at a site before an evaluation of the training capacity of that site can be made. This section describes the collection and analysis of training resource availability data and presents results for each AFS.

6.1 Procedure: Data Collection

The complete AFS-specific resource list, the development of which was described in Section 4.0, formed the basis for the collection of resource availability data. For units to which airmen from the AFS were assigned at operational bases (and hence where OJT was provided), two estimates were requested for each resource:

1. The quantity available for use in OJT in the AFS; and
2. The number of hours per day, week or month that the item is available for use.

In order to facilitate characterization of representative sites for the specialty, each of the operational units providing training resource availability data was asked to furnish certain other information. For all four AFSs, operational units were asked to indicate:

1. Base name and unit designation;
2. The number of airmen by grade in the unit; and
3. The average number of hours per month that an airman in each grade was typically available for conducting OJT.

For the aircraft maintenance specialties, 328X4 and 423X1, information on the type of aircraft supported and the number of aircraft of each type was also requested. In the Electronic Computer and Switching Systems Specialty (305X4), the respondent was asked to provide a list of the equipment that the unit was responsible for maintaining. Finally, for the Security Police Specialty (811XX), the respondent was given a list of 11 security missions or functions and asked to select the function or functions that best described the activities of the unit.

The Occupational Survey Report (OSR) data base was used to identify the operational units to which airmen in each AFS were assigned. Any unit having at least two members (one member for

AFS 811XX) in any of the four pertinent AFSs was designated as a potential recipient of questionnaires. Units were then grouped by specialty and base; and questionnaires were mailed to the Survey Control Officer at each base with instructions to distribute the questionnaires to the senior noncommissioned officer in each pertinent AFS in the designated units (see Appendix E, Section 1.0).

The collection of resource availability data from FTDs and TTCs was accomplished as part of the resource requirement and FUS data collection efforts described in Section 5.1 (see Appendix E, Section 2.0). In addition to estimates of the quantity of each type of resource available for use in the course and the amount of time during which the resource item typically is available, the course instructor was also asked to identify other courses with which the resource item is shared, and to indicate whether the resource item is also shared with operational activities.

6.2 Procedure: Data Analysis

OJT occurs in virtually every operational unit within the Air Force. Rather than developing a separate representation for each of these units, a much smaller number of representative sites were modeled for use in the RCS. Each representative site corresponded to some number of actual units which were similar in terms of the resources available for training and the operational mission of each unit.

The approach selected for creating the groupings of similar units (i.e., for defining representative sites) was cluster analysis. The purpose of cluster analysis is to place objects into groups or clusters suggested by the data (not defined a priori), such that objects in a given cluster tend to be similar to each other in some sense, and objects in different clusters tend to be dissimilar. Utilizing the resource availability data collected from operational units (described in Section 6.1), the clustering algorithm was used to identify groups of units within specialties according to their similarities in:

1. The types of resources available for training;
2. The number of airmen by grade;
3. Major command (328X4 and 423X1 only);
4. The type of aircraft supported (328X4 and 423X1 only);
5. The types of equipment maintained (305X4 only); and
6. The mission(s) of the unit (811XX only).

Except for the number of airmen by grade, these data items were represented by a set of binary variables.

The SAS Statistics software package was used to implement the clustering algorithm. Various clustering methods are available in this package. The methods differ primarily in terms of how the distance between two clusters is computed. Two of these methods, the Average Linkage Method and Ward's Minimum Variance Method (both of which are also available in the Comprehensive Occupational Data Analysis Programs [CODAP]), were tested and the resulting clusters were compared. The Average Linkage Method tended to create one very large cluster with a few smaller ones, whereas Ward's Method typically produced clusters with roughly the same number of observations. As Ward's Method tended to produce results that were more useful in the development of representative sites, this method was selected.

Once representative sites were defined in terms of the operational units corresponding to each site, it became feasible to calculate the amounts of resources available at each representative site. However, several data problems had to be resolved first. Quite a few non-quantitative responses had been received. These responses were of two general types:

1. A response indicating that an unlimited quantity of a particular resource was available for use in providing training; and
2. A response indicating that a resource was available, but providing no indication of what quantity or for how much time.

In the first situation, "unlimited" was equated with the greatest availability shown for that particular resource within the corresponding cluster or group of sites. If no other respondent within the group had indicated that that particular resource was available for the provision of training, then availability was not quantified.

In the second situation described above, availability was also not quantified. However, for these cases an indicator was included in the data base to specify explicitly that resource availability was not quantifiable.

Several methods were available for the calculation of the amounts of resources available for the provision of training at each representative site. The use of both the mean and the median response for each resource was considered. In addition, a decision had to be made as to whether a non-response should be treated as a true zero (i.e., that the resource was not available for use in providing training at the site). Mean and median resource availabilities were calculated in hours per year for each resource at each representative site. One set of calculations interpreted the non-responses as zeroes in computing mean and median resource availabilities, and a second set of

calculations used only the non-zero responses in computing those values. After an examination of the results of each of the four estimation procedures, the decision was made to use the median response from the group of units that furnished non-zero responses.

The development of the techniques used for the calculation of resource requirements at a site was described in Section 5.0. These techniques required inputs from the FUS detailing the training that members of an AFS need to receive. The FUS describes training needs in terms of the number of hours of training that airmen in a particular job should receive, by TTM and training setting. Thus, for the RCS to calculate total resource requirements for a representative site, a method for distributing the airmen in a particular job among the different representative sites was required. The OSR data base provided a means of accomplishing this task.

Each respondent in the OSR data base has indicated the unit to which he or she is assigned, the tasks currently performed, and an indication of the amount of time spent performing each task. Using CODAP, it is possible to generate a hierarchical clustering of all jobs in the AFS based on the similarity of the tasks performed (Christal, 1974). Each Air Force unit can then be characterized in terms of a job profile; i.e., the number of respondents in that unit performing each of the jobs in the AFS.

Starting with the groupings of units (representative sites) defined by the cluster analysis, it was then necessary to associate each of the units not included in the cluster analysis with one of the representative sites. Discriminant analysis procedures were ideally suited to accomplishing this task.

In particular, given a data file containing a set of observations on one classification variable and several quantitative variables, discriminant analysis can be used to derive a mathematical rule or discriminant function for determining to which of the classes defined by the classification variable each observation belongs, based on the values of the quantitative variables for that observation. In the case at hand the classification variable was the representative site to which an operational unit was assigned in the cluster analysis; and the quantitative variables were the profiles of numbers of airmen by job for each operational unit, generated from the OSR data base.

Using the discriminant analysis procedures in the SAS Statistics software package, each unit not assigned to a representative site in the cluster analysis was assigned to one of the representative sites on the basis of the derived discriminant function. Next, the numbers of airmen in a particular type of job in each operational unit associated with each representative site were totalled across all units associated with that representative site, and this sum was divided by the number of airmen in that same type of job.

throughout the entire Air Force. The quotient was then applied in the RCS as an estimate of the proportion of the airmen entering that job who should be distributed to that representative site.

6.3 Results for TDS Specialties

In this section, the results of the data collection and analysis efforts undertaken to determine the amounts of resources available for the provision of training are presented.

Analysis of the OSR data base indicated that, across the four AFSs at the time of the survey, 644 Air Force units had two or more airmen (one or more in AFS 811XX) in the TDS AFSs assigned to them. Resource Availability Questionnaires with usable responses were returned by 270 units, resulting in a response rate of 41.9%. Response rates by AFS were fairly consistent, ranging from a low of 37.7% in AFS 305X4 to a high of 44.3% in AFS 328X4. These results are summarized in Table 5.

Based on the data reported for those units on the Resource Availability Questionnaires, the units were sorted into groups using the SAS Clustering Procedure. More precisely, the groups were formed on the basis of the criteria delineated in Section 6.2 above, using the algorithm for Ward's Minimum Variance Method contained in the SAS Clustering Procedure.

The data collected on the completed Resource Availability Questionnaires for each of the groups of units were then used to define the characteristics of a representative site corresponding to that group of units. As described in Section 6.2, the availability of any resource for the provision of training at each of the representative sites was estimated as the median of the positive amounts of that resource reported to be available for that purpose on the questionnaires returned for the actual units associated with that representative site.

In marked contrast to the number of resources available for the provision of training at a site, however, analysis of the resource requirements data described in Section 5.0 reveals that the number of non-personnel resources that might be required for the provision of OJT at a site is, on average across the TDS AFSs, 52% larger than the number of resources available. This disparity clearly suggests that many types of resources potentially needed for the provision of OJT are not reported to be available in units where airmen requiring that training are assigned. Furthermore, for all of the representative sites, some types of resources reported to be available for the provision of training are not among the types of resources that might be required for the provision of OJT.

**Table 5. Operational Unit Resource Availability
Survey Results**

	Specialty				
	305X4	328X4	423X1	811XX	Total
Number Mailed	138	115	181	210	644
Number Returned	52	51	78	89	270
Response Rate	37.7%	44.3%	43.1%	42.4%	41.9%

However, the absence of sizable and widespread breakdowns in the provision of OJT clearly demonstrate that the above described discrepancies are not evidence of serious problems in the delivery of OJT but, more realistically, are evidence of clear shortcomings in the data collection procedures used in the initial application of the RCS. The precise nature, possible sources and likely consequences of these shortcomings are discussed in greater detail in Sections 8.0 and 9.0.

In addition to comprising the basis for developing resource availability estimates for the representative sites, the AFS-specific groups of Air Force units formed using the SAS Clustering Procedure were also utilized as inputs into the SAS Discriminant Analysis Procedure so that a statistical basis could be established for associating with one of the representative sites in an AFS each Air Force unit that did not respond to the Resource Availability Questionnaire. In particular, using job profiles developed from the OSR data base for the units that responded to the questionnaire, the discriminant analysis procedure derived a separate discriminant function for each of the groups of units. Those discriminant functions were then evaluated for the job profiles developed from the OSR data base for each of the other units which had airmen from the specialty; and, based on the computed values, each unit was associated with one of the groups of units formed by the clustering procedure.

7.0 ESTIMATION OF TRAINING COSTS

This section describes the manner in which training costs are evaluated in the RCS. This evaluation involves: the development of unit cost factors, the estimation of travel cost, and the accumulation of training costs at various training sites.

7.1 Development of Unit Cost Factors

For each type of resource for which annual recurring expenditures are incurred as a result of the provision of training, a unit cost factor must be developed indicating the variable cost typically incurred during a year when the resource is used in the provision of training. For resources that are completely expended during training (e.g., ammunition), the appropriate unit cost factor is the price of the resource. For labor resources, that price corresponds to the total payment made to or on behalf of the trainee or trainer.

As described in Section 5.1, the data collected to describe resource requirements in the RCS indicate the amounts of time that specific types of resources are required for the provision of training. This approach has been adopted because the principal annual recurring costs associated with the provision of training are the salaries of trainers and trainees. As a result of this emphasis, however, no resource requirements data were collected for the few resources that are completely consumed in the provision of training. Since the prices of these resources are uniformly comparatively low for the four TDS specialties, their omission should cause only an inconsequential underestimation of training costs.

For labor resources, the appropriate unit cost factors are the hourly salaries of the trainees and trainers. Two data sources were used in determining the relevant hourly salaries for evaluating training costs for a specialty in the RCS:

1. The table entitled "Monthly Military Basic Rates of Pay" in Air Force Magazine, May 1987, p. 82; and
2. The OSR data base.

In "Monthly Military Basic Rates of Pay," salaries are tabulated by grade and years of experience. The grade and years of experience for each respondent to the Occupational Survey are recorded in the OSR data base. In addition, each respondent can be associated with a particular job on the basis of the KPATH

number associated with the respondent in the OSR data base.⁵ Thus, using the information recorded for all respondents associated with a specific job, an average grade and years of experience can be calculated for each job in the specialty. Then, the monthly rate of pay for that grade and those years of experience can be assigned to that job from the table of "Monthly Military Basic Rates of Pay." Conversion of that monthly rate to an hourly rate is straightforward, involving only division by 173.3 hours per month.⁶ This computational sequence yields the desired unit cost factors for trainees.

In deriving unit cost factors for OJT trainers, it was assumed that, on average, the trainers for each job would be slightly more senior than the airmen they are training. In assigning a specific hourly salary to a trainer for each job, the following approach was utilized:

1. If the average trainee grade for a particular job had been rounded downward (e.g., if the average grade for a job was 4.3, then a grade of 4 was used to determine the rate of pay for a trainee for that job), then the grade of the trainer was defined as the next higher grade with the same years of experience.
2. If the average trainee grade for a particular job had been rounded upward, then the grade of the trainer was set equal to that of the trainee, but the next higher number of years of experience was used to determine the rate of pay.

In order to determine rates of pay for trainers at TTCs and FTDs, the OSR data base was again utilized. Airmen in these jobs had the letter "T" appearing in their records. Also, by referring to the base and unit to which each of those airmen was assigned, it was possible to differentiate between TTC and FTD trainers. Average grades and years of experience were then calculated and rates of pay were assigned in the same manner used to compute unit cost factors for trainees.

For long-lived resources such as equipment or classroom facilities, the appropriate unit cost factor consists of the total cost generally incurred in operating and maintaining a unit of the resource used for the provision of training throughout the year. Developing such unit cost factors usually involves apportioning aggregate estimates of operating and maintenance

5 A KPATH number is an index assigned by the clustering procedure used to determine the jobs in an AFS. The index indicates the point at which an individual entered the cluster corresponding to a particular job.

6 This factor is the product of (40 hours per week) times (52 weeks per year) divided by 12.

costs among the various types of resources to which the aggregate estimates pertain. Aggregate estimates of operating and maintenance costs attributable to training activities have been developed by the ATC Cost Analysis Directorate (ATC/ACC). However, among the TDS specialties, such estimates were available only for the TTC courses in AFSs 305X4, 328X4, and 423X1 taught at Chanute and Keesler AFBs. The estimates of costs of materials were quite low, never exceeding \$0.83 per student week. Estimates of labor costs were substantially higher, reaching \$76.43 per student week for a few of the more advanced courses taught at TTCS. However, on average, these labor costs are less than \$10.00 per student week. At this stage in both the development of the TDS and the estimation of operation and maintenance costs attributable to training activities, no such estimates were included among the RCS unit cost factors.

7.2 Estimation of Travel Cost

To estimate the costs of travel associated with the provision of training, two tasks had to be accomplished:

1. Determination of the origins and destinations of travel for training; and
2. Association of a suitable travel cost estimate with each feasible origin/destination pair.

In the first task, the determination of destinations was simply a matter of identifying the Air Force bases at which each TTC and FTD course was taught. (There is no travel cost associated with OJT.) Air Force Regulation (AFR) 50-5, USAF Formal Schools, contains this information. Since the same FTD course may be taught at several bases, the prime, coordinating, and using FTDs were all listed for each course.

Originating points of travel are the bases at which airmen in each specialty are located. Within the TDS, the FUS determines the number of airmen in a particular job who need to take a course. These airmen are allocated among bases in the RCS according to the distribution of airmen in that job and specialty indicated in the OSR data base. It should be noted that certain courses, such as the initial group of TTC courses taken by all airmen in a specialty and some professional military education (PME) courses taught at each base, do not require TDY travel. The RCS does not calculate travel costs for these courses.

The first step in the process of developing travel costs for each feasible origin/destination pair was to establish a zone system. Nine Continental United States (CONUS) zones were established, as well as five others -- Europe, Pacific, Greenland/Iceland, Alaska and Panama. The zone structure and the assignment of Air Force bases to zones are reported in Appendix F.

The establishment of a zone system greatly reduced the number of airfares that had to be estimated, as there were significantly fewer pairs of zones than pairs of bases.

Zone-to-zone airfares were estimated on the basis of the distances between major cities in each of the zones. The unit costs per mile indicated in Table 6 were used to estimate airfares. These unit costs per mile produced estimated airfares that roughly approximate a sample of U.S. Government rate fares obtained from AFHRL personnel, for travel from San Antonio to a number of major U.S. cities.

In addition to zone-to-zone airfares, an additional travel cost factor was associated with each Air Force base. For CONUS bases, this factor was the approximate cost to the Air Force of an airman using a private vehicle to drive from the base to the closest major airport. For bases in other zones, the factor reflected additional distance between the base and the CONUS (e.g., Royal Air Force [RAF] bases have an additional travel cost factor of \$20.00 associated with them, while bases in Turkey have an additional \$125.00 associated with them).

Thus, when travel between a pair of bases is required for training, the RCS calculates a travel cost which includes a round trip airfare between the zones in which the bases are located plus the additional travel cost associated with each of the bases. Also, an estimated per diem cost for a time period equal to the course length (from AFR 50-5) plus 2 days of travel is included as an additional cost factor. The per diem rates used in the RCS are \$16.00 per day for basic courses and \$18.00 per day for higher level courses, provided the stay at the TTC is less than 20 weeks. If the stay exceeds 20 weeks, the travel is no longer considered TDY, and the per diem no longer applies.

7.3 Accumulation of Training Cost Data

Using data from the FUS describing the training requirements associated with any current or alternative U&T pattern, the RCS develops estimates of the training costs associated with that U&T pattern. Basically, costs are estimated for individual training states at particular locations, and those estimates are summed appropriately to calculate training costs for more aggregated organizational levels within the Air Force. Thus, for OJT, costs are computed for each job at each representative site; and for TTC and FTD training, cost estimates are derived at the course level, with direct labor, travel, and per diem costs estimated separately for each course. Estimates for entire representative sites, Air Force bases, major commands or the total Air Force may then be calculated by adding together the cost estimates developed for the individual training states associated with those higher organizational levels.

Table 6. Unit Travel Cost Per Mile,
by Length of Trip

<u>Length of trip (in miles)</u>	<u>Unit cost per mile</u>
0 ~ 499	\$0.15
500 ~ 999	\$0.13
1,000 ~ 1,499	\$0.12
1,500 ~ 1,999	\$0.11
2,000 ~ 2,499	\$0.10
2,500 +	\$0.09

7.4 Results for TDS Specialties

This section first presents the unit cost factors for personnel and the travel cost factors that were developed for use in the estimation of training costs, and then provides estimates of aggregate training costs that were computed on the basis of those cost factors. The manner in which the cost factors were developed was described in Sections 7.1 and 7.2.

Table 7 provides the one-way airfares for travel within the CONUS and one-way airfares for inter-zone travel between the CONUS and the other five regions delineated in the RCS. Inter-zone CONUS airfares range from a low of \$58.00 for travel between the Mid Central and the South Central regions, to a high of \$275.00 for travel between the New England and the Southwest regions. Travel between Europe and the CONUS costs at least \$300.00 one way, and travel between Asian bases and the CONUS costs at least \$400.00.

Table 8 summarizes the results of sorting the OSR data base into job categories, calculating average grade and years of Air Force experience for each job, and associating monthly and hourly salaries with each job based on the average grade and years of experience for the job. These job-specific salaries were determined in the manner described in Section 7.1. The salaries of OJT trainers, calculated in the same manner, and the estimated salaries of TTC and FTD trainers, also derived through analysis of the OSR data base, are presented in Table 9.

Estimates of the total direct training costs for formal-course-type training and OJT were developed for the four TDS specialties for the current U&T pattern and for each alternative U&T pattern. These total cost estimates are described and compared for the individual AFSSs in Sections 7.4.1 through 7.4.4. Examples of more detailed cost estimates developed by the RCS are presented in Section 7.4.5.

7.4.1 Total Direct Training Cost Estimates for AFS 305X4

Table 10 presents total direct training cost estimates for AFS 305X4. Alternative 1 involves merging seven basic resident courses at three TTCs into a common Airman Basic Resident (ABR) course at one location. Though this would result in a moderate cost savings (2.1%, or less than \$200,000) in comparison to the current U&T pattern, it involves the risk of providing some inappropriate training. This alternative was not among those that were highly preferred by AFS functional managers.

Alternative 2 involves flowing all cross-trainees (airmen transferring from another specialty) through an Airborne Warning and Control System (AWACS) FTD to employ their higher maturity (and previously gained experience) in this critical operation. The cost of such an option is modest; an increase of only 3.9%.

Table 7. One-Way Airfares Used in the Estimation of Costs (in \$) for Interregional Travel^a

Region of origin	Region of destination								
	1	2	3	4	5	6	7	8	9
1	--	137	157	204	211	273	247	206	248
2	137	--	171	168	168	275	238	210	220
3	157	171	--	76	126	191	174	100	166
4	204	168	76	--	58	182	150	91	116
5	211	168	126	58	--	200	165	122	105
6	273	275	191	182	200	--	66	127	128
7	247	238	174	150	165	66	--	93	82
8	206	210	100	91	122	127	93	--	95
9	248	220	166	116	105	128	82	95	--
10	550	550	475	450	450	300	300	400	350
11	400	400	550	550	550	650	650	600	650
12	500	575	430	450	475	310	335	335	430
13	165	300	325	370	375	440	415	370	415
14	360	315	270	240	200	240	225	225	195

^a The estimated airfare for intraregional travel is \$40.

Key to regions:

1	Northwest	8	Midwest
2	Southwest	9	Southeast
3	North Central	10	Europe
4	Mid Central	11	Pacific
5	South Central	12	Greenland/Iceland
6	New England	13	Alaska
7	Mid Atlantic	14	Panama

**Table 8. Summary of Job-Specific Salaries by AFS
Based on the OSR Data Base**

AFS	Number of jobs	Minimum trainee salary	Maximum trainee salary
305X4	35	\$874 per month or \$5.05 per hour based on an average grade of 2.6 and an average of 4.9 years of Air Force experience	\$1,680 per month or \$9.70 per hour based on an average grade of 6.8 and an average of 17.4 years of Air Force experience
328X4	27	\$738 per month or \$4.36 per hour based on an average grade of 4.9 and an average of 3.1 years of Air Force experience	\$1,468 per month or \$8.48 per hour based on an average grade of 17.4 and an average of 6.4 years of Air Force experience
324X1	10	\$738 per month or \$4.36 per hour based on an average grade of 2.1 and an average of 4.9 years of Air Force experience	\$1,379 per month or \$7.96 per hour based on an average grade of 5.8 and an average of 17.4 years of Air Force experience
811XX	85	\$808 per month or \$4.67 per hour based on an average grade of 3.1 and an average of 1.9 years of Air Force experience	\$1,680 per month or \$9.70 per hour based on an average grade of 7.0 and an average of 18.2 years of Air Force experience

Table 9. TTC and FTD Trainer Salaries by AFS

AFS	Average grade	Average years of Air Force experience	Salary per month	Salary per hour
TTC Trainers				
305X4	5.6	12.1	1,379	7.96
328X4	4.9	7.6	1,152	6.65
423X1	4.3	5.0	980	5.66
811XX	6.3	10.7	1,311	7.57
FTD Trainers				
305X4	6.1	14.2	1,422	8.21
328X4	6.3	14.7	1,422	8.21
423X1	6.4	14.8	1,422	8.21
811XX	AFS 811XX has no FTD courses			

Table 10. Comparison of Current and Alternative Air Force-Wide Training Costs (000's of \$'s): AFS 305X4*

U&T pattern	Formal course training costs (In Thousands of Dollars)	OJT costs	Total costs	Percent change
Current U&T pattern	2,788	4,926	7,714	Baseline
Alternative 1 (Common ABR; intensive OJT)	2,540	5,011	7,551	- 2.1%
Alternative 2 (Cross-trainees to AWACS)	2,900	5,112	8,012	+ 3.9%
Alternative 3 (One ABR; intensive FTD)	5,424	4,065	9,489	+ 23.0%
Alternative 4 (30-Week ABR; no FTDs)	3,214	4,802	8,016	+ 3.9%
Alternative 5 (Electronics Principles in Community College)	2,569	5,248	7,817	+ 1.3%
Alternative 6** (Merge/separate AFSs)	-----	-----	-----	-----

*Based on data runs of July 1988 (validated August 1989).

**Involves transfer of some jobs and merger with other specialties (for which no TDS data are available).

It was a possible change highly favored by AWACS personnel but not highly regarded by other AFS managers.

Alternative 3 was a proposal for relying on one ABR course and intensive use of FTDs as a means for specializing personnel on equipment and systems. This proved to be the most expensive alternative, with most of the growth in expense occurring in formal courses (ABR and FTDs) and little change in OJT costs. Since an Air Force decision had recently been made to restructure AFS 305X4 by transferring some jobs (plus associated ABRs and FTDs) to another specialty, the Alternative 3 proposal was not highly rated by functional managers.

The other alternative U&T patterns had very little impact on total training costs for the specialty. The actual Air Force decision to separate some AFS 305X4 jobs and transfer them to another specialty was roughly approximated by Alternative #6 (although some of the details were slightly different). The other specialties involved were not specialties which had been included in the TDS prototype development effort, and thus data for evaluating both the aggregate cost impact of this change and its relative cost impacts on the individual specialties were not available for TDS analysis.

7.4.2 Total Direct Training Costs Estimates for AFS 328X4

In Table 11, the total direct training cost estimates for AFS 328X4 are presented. The most notable change for this specialty is associated with Alternative 1, which attempts to provide more training at the TTC by incorporating training now received in FTDs into two trailer courses* (one for Tactical Air Forces [TAF] jobs and the other for SAC and Military Airlift Command jobs), and by limiting FTD attendance for first assignment personnel. While this change in training pattern would provide some relevant training at the TTC, the limitation on FTD attendance forces more of the system-specific orientation to be provided in OJT, thus considerably increasing OJT costs and total AFS training costs (by 45.4 percent), with the major commands bearing the brunt of this increase. (The question then becomes whether operational units have the training capacity to provide that much OJT. In this case, they do.)

The other alternatives that were evaluated for this specialty included attempts to reduce initial skills training, to increase flows of personnel across major commands and thereby broaden the experience base, to experiment with an Aircraft Principles course, and to channel personnel into relevant assignments based on Special Experience Identifiers (SEIs) relating to specific equipment. The cost consequences of these alternatives are shown in Table 11, and range from +24.2% to -0.6%. In most instances, the major impact is an increase in the

* A trailer course immediately follows an ABR course.

Table 11. Comparison of Current and Alternative Air Force-Wide Training Costs (000's of \$'s): AFS 328X4*

U&T pattern	Formal course training costs	OJT costs	Total costs	Percent change
(In Thousands of Dollars)				
Current U&T pattern	2,043	4,445	6,488	Baseline
Alternative 1 (Two-track ABR; limit FTDs)	2,076	7,358	9,434	+ 45.4%
Alternative 2 (Electronics Principles only in ABR; expanded OJT)	1,823	6,233	8,056	+ 24.2%
Alternative 3 (Major command cross flow)	2,519	4,797	7,316	+ 12.8%
Alternative 4 (No technical school)	1,191	6,299	7,490	+ 15.4%
Alternative 5 (SEI by equipment)	1,798	4,647	6,445	- 0.6%
Alternative 6 (Rivet Workforce** merger)	-----	-----	-----	-----

* Most current data runs as of August 1989.

** Rivet Workforce involves merger with other specialties (for which no TDS data are available) at advanced skill levels in order to broaden technical skills.

cost of OJT, with varying levels of increase indicated. Only in the case of Alternative 5 do the savings in formal course training costs more than offset the increase in costs of OJT.

7.4.3 Total Direct Training Cost Estimates for AFS 423X1

Table 12 presents the total direct training cost estimates for AFS 423X1. The most substantial impact on total annual training costs in this specialty involves Alternative 2, where a two-track ABR course was proposed in combination with restricted use of FTD courses by initial assignment personnel. Such a proposal increases the costs of formal course training at the TTC but, by restricting systems-specific training in FTDs, also increases the cost of OJT. The total cost increases by 21.1%, which is shared between the TTC and the major commands.

For Alternative 1, which involves eliminating three small first jobs from the AFS and routing all new personnel through the main Environmental Systems Maintenance (ESM) job type, the change in flow was modeled as a reduction in the number of personnel entering the career field. This results in an overall cost reduction of about 13%; this saving is shared between the TTC and the OJT programs.

For the other alternatives, fairly moderate cost consequences were estimated to result from the various proposed changes. Somewhat surprisingly, Alternative 5, which involved routing all new personnel to initial TAF assignments, results in an overall cost savings of 16.5%. Since all personnel attend the ABR, these savings must be the result of decreased use of FTDs. The increased OJT required is rather limited, and its cost is more than offset by savings in formal school costs.

7.4.4 Total Direct Training Cost Estimates for AFS 811XX

Finally, in Table 13, the total direct training cost estimates for AFS 811XX are presented. The most substantial change in training costs in this specialty is associated with Alternative 1, which involves having all AFS 811XX personnel attend Air Base Ground Defense (ABGD) training (as opposed to the roughly 30% for AFS 811X0 and approximately 10% for AFS 811X2 who attend that training currently). In addition to increasing ABDG formal course attendance, this alternative also adds ABGD task modules to every job, fulfilling the need for readiness sustainment training (exercises and practice) at every location. This change, which was the alternative most preferred by AFS 811XX functional managers, results in a roughly 40% increase in total training costs for these specialties.

[Note: The model developed to analyze Alternative 1 does not include the one-time added costs of moving the ABGD training program from Camp Bullis, Texas to Ft. Dix, NJ, where it will be

Table 12. Comparison of Current and Alternative Air Force-Wide Training Costs (000's of \$'s): AFS 423X1*

<u>U&T pattern</u>	<u>Formal course training costs</u>	<u>OJT costs</u>	<u>Total costs</u>	<u>Percent change</u>
(In Thousands of Dollars)				
Current U&T pattern	1,929	531	2,460	Baseline
Alternative 1 (All to an initial ESM assignment)	1,661	478	2,139	- 13.0%
Alternative 2 (Two-track ABR; no FTDs)	2,405	574	2,979	+ 21.1%
Alternative 3 (Aircraft Principles to FTDs)	2,018	745	2,763	+ 12.3%
Alternative 4 (No ABR; FTDs; contract for some jobs)	1,907	720	2,627	+ 6.8%
Alternative 5 (ABR to TAF assignment)	1,487	568	2,055	- 16.5%
Alternative 6 (Rivet Workforce** merger)	-----	-----	-----	-----

* Most current data runs as of September 1989.

** Rivet Workforce involves merger with other specialties (for which no TDS data are available) at advanced skill levels in order to broaden technical skills.

Table 13. Comparison of Current and Alternative Air Force-Wide Training Costs (000's of \$'s): AFS 811XX*

<u>U&T pattern</u>	Formal course training costs	OJT costs	Total	Percent Change
Current U&T pattern	24,295	14,987	39,282	Baseline
Alternative 1** (All receive ABGD training)	31,478	21,386	52,864	+ 34.6%
Alternative 2 (Merge fields at 7-level)	24,814	15,492	40,306	+ 2.6%
Alternative 3 (Separate into 4 career ladders)	24,049	14,947	38,996	- 0.7%
Alternative 4 (Transfer out administrative jobs)	22,739	15,351	38,090	- 3.0%
Alternative 5*** (By-pass Community College Law Enforcement graduates)	24,052	14,987	39,039	- 0.6%
Alternative 6 (Contract for some jobs)	22,493	13,833	36,326	- 7.5%

* Most current data runs as of 20 September 1989.

** Does not include transfer of ABGD Training to Ft. Dix, N.J.
(Oct. 1987).

*** Calculated as a 5% reduction of Law Enforcement ABR
attendance (approximately 1% of total formal school costs) with
no reduction in OJT costs.

conducted by the U.S. Army (as of 1 October 1987), nor the added annual travel costs for sending all new AFS 811XX personnel TDY to Ft. Dix from the Security Police Academy (the ABR location) enroute to their initial duty assignments. Presumably, those individuals selected for the Military Working Dog (MWD) program would return to Lackland AFB, Texas for their MWD training immediately after ABGD training or subsequent to an initial assignment (although other possible configurations are plausible and should be examined).]

Alternative 2 involves merging the Law Enforcement and Security career fields at the 7-skill level (rather than at the 9-skill level), in order to broaden the experience base of senior noncommissioned officers (NCOs). This merger results in an increase in costs of about \$1 million. Part of this increase stems from a new, merged 7-level course which would be slightly longer than the present ALR81170 and ALR81172 courses. In addition, there would be increased OJT costs resulting from the increased probability that NCOs who were originally assigned to Law Enforcement would subsequently be assigned to Security, and vice versa.

Alternatives 3 and 5 have no important impact on total training costs for AFS 811XX (-0.6% to -0.7%, which is, for all practical purposes, no change). Alternative 4 involves transferring out administrative jobs (Pass and ID, etc.) to other specialties; this would result in a 3% savings in total training costs.

Alternative 6 represents contracting for some AFS 811XX jobs with the civilian workforce in noncombatant major commands (Air Force Logistics Command, Air Force Systems Command, etc.), and results in a cost reduction of about 7.5%. This is a savings for AFS 811XX training, but may not result in any real savings in the overall cost of Air Force operations and training, since contractor or Federal Service personnel would be paid for performing these functions.

7.4.5 Detailed Training Cost Estimates

Examples of the detailed cost reports that the RCS is capable of generating are presented in Tables 14 through 16. Tables 14 and 15 provide compilations of the various types of costs associated with the provision of formal-course-type training, the duration and number of students for each course, and the cost per student week for each course. Weighted average costs per student week are also displayed for three course groups -- FTD, Professional Military Education (PME), and TTC. Table 16 displays direct OJT costs by job for trainees and trainers. More detailed OJT cost tables, showing unit-level costs for representative sites, appear in Rueter *et al.* (1988a, 1988b, 1988c, 1988d).

Table 14. Costs Associated With Formal Course Training in AFS 328X4: Current U&T Pattern

Course	Trainee DTC	Trainer DTC	Per Diem	Transport	Total Costs
1 002	11799	2316	9622	20263	44000
2 009	3237	504	2536	2534	8811
3 014	11494	1382	8131	24643	45650
4 030	21700	2623	14844	24919	64086
5 041	32561	6259	27688	39623	106131
6 046	11360	1975	9903	30367	53605
7 047	4075	1950	2846	20901	29772
8 048	16729	3617	13013	24999	58358
9 049	2396	358	2134	5070	9958
10 050	8375	1095	6979	6204	22653
11 052	3394	665	2076	4080	10215
12 090	5348	859	1739	14038	21984
13 096	19026	2955	13219	24405	59605
14 102	18272	2765	17952	14768	53757
15 117	25161	4383	16638	21927	68109
16 123	44905	7567	31725	35859	120056
17 124	8422	999	7958	6719	24098
18 125	28451	4949	26204	13491	73095
19 126	1103	142	450	1966	3661
20 127	25092	2990	9324	10324	47730
21 128	1739	285	1361	1037	4422
22 129	12717	1430	9851	13623	37621
23 131	1965	483	2727	5395	10570
24 3A2R32854	15521	1213	10227	13238	40199
25 PME-1	17249	897	0	0	8146
26 PME-2	0	0	0	0	0
27 Leadership School	16824	2112	0	0	18936
28 Maj Comm NCO Acad	2588	197	0	0	2785
29 Senior NCO Academy	0	0	0	0	0
30 ABR Course	1539169	137184	0	0	1676353
Total	1900672	194154	249147	380393	2724366

*DTC - Direct Training Cost

Table 15. Course Duration, Number of Students and Cost Per Study Week
in AFS 328X4: Current U&T Pattern

Course	Course Duration	Number of Students	Cost per Student week	
			FTD	PME
1 002	1 week(s)	2 day(s)	52.4	599.78
2 009	4 week(s)	5.3	415.60	
3 014	1 week(s)	4 day(s)	38.2	663.88
4 030	2 week(s)	3 day(s)	52.0	474.00
5 041	3 week(s)	2 day(s)	74.4	475.50
6 046	1 week(s)	2 day(s)	52.7	726.56
7 047	0 week(s)	2 day(s)	40.4	1842.42
8 048	2 week(s)	2 day(s)	54.7	533.43
9 049	1 week(s)	2 day(s)	11.1	640.81
10 050	4 week(s)	2 day(s)	14.5	355.06
11 052	2 week(s)	3 day(s)	7.3	538.14
12 090	0 week(s)	2 day(s)	34.0	1616.49
13 096	2 week(s)	2 day(s)	57.8	429.68
14 102	4 week(s)	2 day(s)	34.2	357.24
15 117	3 week(s)	3 day(s)	47.3	479.98
16 123	3 week(s)	3 day(s)	76.9	433.67
17 124	5 week(s)	3 day(s)	13.3	362.39
18 125	7 week(s)	4 day(s)	32.4	322.29
19 126	1 week(s)	4 day(s)	4.7	779.01
20 127	3 week(s)	2 day(s)	25.5	623.92
21 128	4 week(s)	2 day(s)	2.7	409.50
22 129	2 week(s)	4 day(s)	29.8	450.88
23 131	2 week(s)	1 day(s)	10.9	484.86
24 3AZR32854	3 week(s)	2 day(s)	25.8	458.27
25 PME-1	1 week(s)	4 day(s)	67.5	67.04
26 PME-2	2 week(s)	4 day(s)	30.4	0.00
27 Leadership School	3 week(s)	4 day(s)	66.0	75.50
28 Maj Comm NCO Acad	5 week(s)	1 day(s)	15.5	34.55
29 Senior NCO Academy	8 week(s)	0.0	0.0	0.00
30 ABR Course	30 week(s)	4 day(s)	450.5	120.81

Weighted Average Cost per Student Week for
1) Based on # of students
2) Based on course length

FTD PME TTC
615.88 55.99 120.81
469.16 54.37 120.81

Table 16. Total Air Force Direct OJT Costs by Job in AFS 328X4: Current U&T Pattern

Job	Trainee DTC	Trainer DTC	Total DTC
1	48692	16806	65498
2	433035	172957	605992
3	123658	46687	170345
4	7564	2827	10391
5	27566	8986	36552
6	115217	48251	163468
7	12625	6138	18763
8	109290	51408	160698
9	47638	26148	73786
10	274987	169681	444668
11	748715	344057	1092772
12	567858	244137	811995
13	137515	63730	201245
14	180306	130174	310480
15	57705	34088	91793
16	19751	14531	34282
17	109007	46596	155603
18	379588	277014	656602
19	12630	8657	21287
20	7326	4025	11351
21	288735	124908	413643
22	41730	14420	56150
23	15682	6032	21714
24	6320	1559	7879
25	31976	10063	42039
26	48751	9647	58398
27	93464	27210	120674
Total	3947331	1910737	5858068

8.0 ESTIMATION OF TRAINING CAPACITIES

Fundamentally, as explained in detail in Section 3.2, the estimation of training capacity involves the derivation of estimates of the ability of individual sites to accommodate differing volumes of training in specific training states. The capacity to provide training is an attribute of a site, and relates to all training conducted concurrently in all training states applicable to the site. Accordingly, estimation of the capacity of a site to provide training involves systematically comparing the amounts of training resources required to conduct the training designated for the site with the amounts of those resources available for the provision of training at the site.

The procedure established to estimate training capacity within the RCS therefore methodically compares the estimated resource availabilities for the representative sites delineated for a specialty to the total amounts of resources required at those sites to accommodate the specific volumes of training in specific training states indicated for those sites within the U&T patterns developed by the FUS. Two basic analytic methods, the ratio method and the mathematical programming method, were implemented in the RCS to perform these comparisons.

The ratio method involves computing the ratio between the total amount of each required resource that is available for the provision of training at each representative site and the total amount of the resource that is actually needed to provide all of the training designated for that site within a particular U&T pattern delineated in the FUS. A calculated ratio greater than or equal to 1.0 then indicates that the available quantity of the corresponding resource is sufficient for provision of the designated amount of training, whereas a ratio less than 1.0 indicates insufficient availability of the resource.

However, because the ratios are based on resource use and not on output production, a calculated ratio less than 1.0 generally does not have an unambiguous relationship to the proportion of the total number of trainees at the site who actually can receive all of the training indicated for them within the U&T pattern. Therefore, in the RCS both an upper bound estimate and a lower bound estimate of the capacity of the site to support that volume of training have been developed based on the ratios computed for the individual resources. As discussed in Section 3.2, the upper bound estimate is based on the assumption that it is possible to concentrate all shortages of required training resources at the site on a restricted group of trainees (e.g., the trainees in a particular training state), and the lower bound estimate is based on the assumption that it is impossible to concentrate resource shortages on particular groups of trainees.

The mathematical programming method, in contrast, provides a means for evaluating the feasibility of allocating training resources in such a way that the trainees to whom training is not provided as a result of the limited availability of one resource are among those to whom training is not provided due to the limited availability of other resources. To the degree that resources can be allocated to produce that outcome, the number of trainees to whom the training designated within a U&T pattern is provided will be increased.

The results obtained when the two methods of training capacity estimation described above were applied to evaluate training capacity for the TDS specialties are summarized below.

Tables 17 and 18 display results derived by applying the ratio method and the mathematical programming method of training capacity estimation, respectively, to data developed in the RCS estimating the amounts of individual resources required and the amounts of those resources available for providing training at an individual unit characterized by a particular representative site. The results presented in these tables relate to representative site 1 from AFS 328X4 for the current U&T pattern.

In Table 17, the numbers entered in the first column index the specific resources to which the estimates relate. The second and third columns then contain the estimates derived in the RCS for the amounts of those resources available and required, respectively, for providing the training designated for the representative site within the U&T pattern. The fourth column presents the ratios of the amounts available to the amounts required for the individual resources. Whenever a ratio reported in the fourth column is greater than or equal to 1.0, the amount of the resource available at the site is sufficient to provide the total amount of training needed at the site to sustain the U&T pattern. Conversely, whenever the reported ratio is less than 1.0, there is a shortage of the resource at that site.

The estimates presented in the fifth and sixth columns, respectively, indicate the maximum numbers of trainees supportable with the amounts of resources available at the site, and the numbers of trainees to whom the FUS has determined training must be provided at the site in order to support the U&T pattern. The estimates of maximum numbers of trainees supportable that are contained in the fifth column of the table were computed by multiplying the corresponding numbers of trainees required, from the sixth column, by the ratios of the amounts of resources available to the amounts of resources required, from the fourth column. Next, the estimates in the seventh column indicate the numbers of airmen to whom training should be provided in order to sustain the U&T pattern, but cannot be provided due to the limited availability of the individual resources. These estimates were calculated by merely subtracting the corresponding estimates in the fifth column from those in the sixth column, and setting the values equal to zero

Table 17. Estimated OJT Capacities Developed by the Ratio Method for Typical Units Characterized by a Representative Site

Training Capacity per Unit for Representative Site: Non-labor Resources
 Representative Site 1 328x4
 Training Capacity: Current U&T Pattern
 - Upper Bound: 0.9848
 - Lower Bound: 0.6400
 Total Trainees Required: 2.8408

Res	Amount Available	Amount Required	Avail/Req	Max Trainee Supportable	Trainees Required	Trainees Unsupportable	Additional Amt Needed
18	5840.00	0.15	38364.9609	66888.0313	1.7435	0.0000	0.00
21	5840.00	0.15	38364.9609	66888.0313	1.7435	0.0000	0.00
27	1800.00	7.59	237.2931	628.5420	2.6488	0.0000	0.00
29	5840.00	11.34	515.0416	1364.2423	2.6488	0.0000	0.00
39	208.00	634.66	0.3277	0.9048	2.7608	1.8560	426.66
68	1560.00	2.60	601.0274	1148.8439	1.9115	0.0000	0.00
73	11680.00	1.22	9582.4980	5026.3403	0.5245	0.0000	0.00
77	5840.00	3.31	1766.7227	3923.0667	2.2205	0.0000	0.00
79	5840.00	0.22	26149.2539	45590.3555	1.7435	0.0000	0.00
91	520.00	0.97	538.5500	999.2617	1.8555	0.0000	0.00
103	11680.00	118.77	98.3422	279.3707	2.8408	0.0000	0.00
104	208.00	3.48	59.8274	63.4649	1.0608	0.0000	0.00
106	5840.00	46.20	126.4130	349.0011	2.7608	0.0000	0.00
113	8760.00	1.62	5407.4072	10033.2646	1.8555	0.0000	0.00
114	8760.00	8.29	1056.1285	2475.2837	2.3437	0.0000	0.00
120	5840.00	0.08	72999.9922	127273.0547	1.7435	0.0000	0.00
126	5840.00	0.03	228521.7344	398420.0313	1.7435	0.0000	0.00
130	5840.00	1.11	5261.2607	2759.7070	0.5245	0.0000	0.00
133	8760.00	11.50	761.7391	1688.4203	2.2165	0.0000	0.00
150	17520.00	79.31	220.9022	627.5390	2.8408	0.0000	0.00
153	8760.00	13.66	641.2884	495.4167	0.7725	0.0000	0.00
157	208.00	4.79	43.4641	89.0377	2.0485	0.0000	0.00
160	52.00	63.45	0.8196	1.5666	1.9115	0.3449	11.45
167	233600.00	0.12	*****	3595231.7500	1.8811	0.0000	0.00
170	26280.00	0.59	44626.4102	83945.2578	1.8811	0.0000	0.00
172	11680.00	114.27	102.2170	290.3782	2.8408	0.0000	0.00
183	8760.00	0.37	23394.6582	12271.2793	0.5245	0.0000	0.00
188	1560.00	47.36	32.9384	43.0922	1.3083	0.0000	0.00
189	5840.00	0.30	19252.7461	33566.5234	1.7435	0.0000	0.00

* indicates that the value is too large for the column format

Table 18. Estimated OJT Capacity Developed by the Mathematical Programming Method for Typical Units Characterized by a Representative Site

Representative Site 1

AFS 328X4

Current U&T Pattern

Linear programming estimate of training capacity: 2.41

Operative resource constraints limiting the maximum quantity of training achievable (for resources available in insufficient amounts to sustain the provision of all designated training):

<u>Resource</u>	<u>Amount available</u>	<u>Amount required</u>
39	208.0	208.0
160	52.0	37.8

whenever the calculated differences were negative. Finally, the eighth column reports, for each resource, the additional amount needed to enable full provision of the training designated for the site. The values in this column were computed by subtracting the corresponding estimates in the second column from those in the third column, and setting the values equal to zero whenever the calculated differences were negative.

At the top of Table 17, three aggregate values are presented that summarize, within the context of the ratio method of training capacity estimation, the cumulative implications of all estimated resource requirements and resource shortages for the provision of the designated training at the representative site. Those values include the upper bound and lower bound estimates of training capacity computed for the site by the ratio method, and the total number of trainees for whom the provision of some amount of training at the site has been designated by the FUS. As explained in Section 3.2, the upper bound estimate of training capacity (0.9848) was calculated by subtracting the maximum value in the seventh column of the table (1.8560, the estimated maximum number of trainees to whom designated training cannot be provided due to a shortage of any individual resource at the site) from the total number of trainees needing some amount of additional training at the site (2.8408). The lower bound estimate of training capacity (0.6400) was then computed by subtracting the sum of the positive values in the seventh column of the table (1.8560 plus 0.3449 or 2.2009, the maximum number of trainees to whom designated training might not be able to be provided due to all shortages of required resources at the site) from the total number of trainees requiring additional training at the site.

Table 18 contains the results developed for the same representative site and U&T pattern when the mathematical programming method was used to estimate training capacity. The estimate of training capacity derived with linear programming was 2.41 trainees per year. This value exceeds the upper bound estimate computed using the ratio method by 1.43 trainees per year or, equivalently, by a multiplicative factor of 2.45. This substantial difference in estimated capacities clearly indicates that the fundamental assumption involved in the calculation of upper bound and lower bound capacity estimates by the ratio method (namely, that the total amount of each resource required per trainee for the provision of training is approximately the same for all training states, and hence for all trainees, at the representative site) is not satisfied for this representative site. As a result, the estimates of training capacity developed for this representative site by the ratio method are extreme underestimates of the actual training capacity. Under such circumstances, the mathematical programming method generates much more realistic estimates of training capacity.

The mathematical programming method also identifies the specific resource that imposes the most restrictive limitation on the capacity of the representative site to accomplish all of the training designated within the U&T pattern. Accordingly, for each resource for which the ratio method estimated that the total amount available was insufficient for providing all of the training designated for the representative site, Table 18 presents both the total amount of the resource available, and the total amount required for providing the maximum quantity of training achievable with the combined amounts of all required resources available at the site.

The estimates reported in the table indicate that the total amount of resource 39 (aircraft) that was available for the provision of training was equal to the total amount required for providing the maximum achievable quantity of training, whereas the total available amount of resource 160 (weapons release control system analyzer) that was available exceeded the amount required for providing the maximum achievable quantity of training by 14.2 units. Thus, in this situation, resource 39 imposes the most restrictive constraint on the training capacity of the representative site. An increase in the amount of resource 39 available at the site would increase the maximum quantity of training achievable at the site. Conversely, for resource 160 (which, like resource 39, is not sufficiently available to sustain the provision of all of the training designated for the representative site) an increase in the available amount of the resource would have no effect on the maximum quantity of training achievable under the prevailing circumstances at the site.

If an ample additional amount of resource 39 were supplied to the site, however, the insufficient availability of resource 160 would become the most restrictive constraint on the training capacity of the site. Application of the mathematical programming method in that situation would indicate that the total amount of resource 160 required for providing the maximum achievable quantity of training was equal to the total amount available, and that the total available amount of resource 39 exceeded the total amount required for providing that quantity of training. Accordingly, in that situation, an increase in the available amount of resource 160 would increase the maximum quantity of training achievable at the site, but an increase in the availability of resource 39 would have no effect on that maximum quantity.

Tables 19 and 20 summarize the results from the ratio method and the mathematical programming method of training capacity analysis for AFSs 328X4 and 811XX, respectively. Each unit characterized by a representative site at which resource shortages occurred is described in these tables. Since no resource shortages impeded designated training in AFSs 305X4 and 423X1, no results are reported for these specialties.

**Table 19. Estimated OJT Capacities for Typical Units
Characterized by Representative Sites with
Resource Shortages in AFS 328X4**

Utilization and training pattern	Total trainees requiring training	Training Capacity		
		Ratio method	Lower bound	Upper bound
Representative Site 1				
Current	2.84	0.64	0.98	2.41
Alternative 1	4.13	0.85	1.07	2.90
Alternative 2	3.30	0.00	0.73	2.10
Alternative 3	6.32	0.00	1.11	2.81
Alternative 4	5.12	0.00	0.93	2.32
Alternative 5	2.73	0.16	0.87	1.83
Representative Site 2				
Current	12.29	0.00	0.77	4.90
Alternative 1	12.86	0.00	0.92	3.71
Alternative 2	11.34	0.00	0.69	3.42
Alternative 3	17.71	0.00	0.76	4.41
Alternative 4	13.78	0.00	0.69	4.91
Alternative 5	11.87	0.00	0.70	2.87

Table 20. Estimated OJT Capacities for Typical Units Characterized by Representative Sites with Resource Shortages in AFS 811XX

Utilization and training pattern ^a	Total trainees requiring training	Training Capacity		
		Ratio method	Lower bound	Upper bound
Representative Site 2				
Current	134.52	0.00	13.69	75.04
Alternative 1	126.89	0.00	12.71	63.31
Alternative 2	151.40	0.00	13.13	85.15
Alternative 3	134.07	0.00	23.31	b
Alternative 4	123.64	0.00	14.38	68.12
Alternative 6	142.24	0.00	14.22	78.61

- a Alternative U&T pattern 5 is identical to the current pattern with regard to OJT resource requirements and availabilities. Thus, separate evaluations of OJT capacity were not performed for that alternative.
- b Numerical problems in computation prevented estimation of OJT capacity by the mathematical programming method for this alternative.

For each representative site with resource shortages and for each U&T pattern,⁷ the following items are reported:

1. The total number of trainees designated for training at each of the units characterized by the representative site;
2. The lower bound estimate of aggregate training capacity computed by the ratio method for each of the units characterized by the representative site;
3. The upper bound estimate of aggregate training capacity computed by the ratio method for each of the units characterized by the representative site; and
4. The estimate of aggregate training capacity computed by the mathematical programming method for each of the units characterized by the representative site.

The results presented in Tables 19 and 20 reveal that, for every U&T pattern examined for each representative site with shortages of required resources, the estimate of training capacity developed by the mathematical programming method was substantially larger than the upper bound estimate of training capacity developed by the ratio method. Thus, under all circumstances analyzed, the mathematical programming method generated much more realistic estimates of the maximum achievable quantity of training than those produced by the ratio method. These results clearly indicate the general superiority of the mathematical programming method as a means for estimating training capacity. However, practical application of the mathematical programming method for a representative site requires knowledge of all resources with shortages at the site; and such knowledge can readily be developed by applying the ratio method to estimates of requirements and availability for all required resources at the representative site. Accordingly, as explained in detail in Section 3.2.3, the best achievable information about training capacity for any specialty can be developed through the complementary use of both the ratio method and the mathematical programming method.

⁷ Descriptions of the U&T patterns analyzed for the four TDS specialties can be found in Rueter et al. (1988a, 1988b, 1988c, 1988d).

9.0 CONCLUSIONS AND RECOMMENDATIONS

Like other TDS subsystems, the RCS is intended to aid in evaluating not only the current U&T pattern, but also a wide variety of alternative U&T patterns that might be implemented within an AFS. To support such diverse evaluations, it is necessary to create a data base containing sufficient detail to permit satisfactory estimation of training costs, training capacities, and associated resource requirements and resource availabilities for all U&T patterns that realistically might be implemented. More specifically, the data base must contain or permit estimation of: (a) the amounts of individual resources required for providing specific amounts of training on specific TTMs in specific training settings, (b) the amounts of those resources available for use in providing training at various sites, and (c) the annual variable costs incurred in using resources in the provision of training.

Thus, the RCS requires data at levels of detail that are considerably greater than those contained in existing Air Force training data bases. Most notably, no existing Air Force data bases contain information on resource requirements and costs for units of training as small as individual TTMs. In addition, measurements of resource availability are not compiled separately for training and operational uses. As a result, development of the RCS data bases necessarily relies heavily on the systematic collection of explicit judgments from SMEs.

The research summarized in this report provided ample proof of the practicality and usefulness of the essential analytic concepts contained in the RCS. However, the research also indicated several ways in which implementation of these concepts might be improved. The potential improvements relate to three distinct aspects of the RCS: (a) the use of SMEs, (b) the data collection instruments and procedures, and (c) the estimation of costs. These three categories of recommended revisions and refinements are discussed successively in Sections 9.1 through 9.3.

9.1 Refined Use of SMEs

To assure that comprehensive evaluation of training costs and training capacities will be possible for an AFS, it is imperative to obtain satisfactory estimates of: (a) the amounts of individual resources required for providing training on each TTM in each training setting, and (b) the amounts of those resources available for the provision of training at all Air Force units to which a substantial number of personnel in the specialty are assigned. Accordingly, to establish an adequate data base to allow the use of linear regression analysis in the statistical estimation of training resource requirement functions for particular resources, TTMs and training settings, it is

necessary to obtain from SMEs at least three distinct judgments of the amounts of resources required to conduct specific amounts of training on each TTM in each training setting. In addition, the judgments must relate to at least two different amounts of training.

Thus, in the resource requirements data collection, SMEs were asked to furnish judgments of the amounts of resources required for both the current allocation and their ideal allocation of TTM training among settings. In this manner, enough data to permit statistical estimation of resource requirement functions for a particular TTM and training setting can usually be obtained from just two SMEs, so long as the SMEs indicate different current and ideal allocations. Consequently, for most TTMs and training settings, obtaining enough SME judgments to permit satisfactory statistical estimation of training resource requirement functions does not involve notable difficulty.

However, many specialties include a few TTMs that consist solely of tasks that are performed by only a small number of personnel in the specialty (e.g., tasks associated with specialized equipment that is available at only a small number of bases). Locating SMEs who are knowledgeable about the provision of training on those TTMs can be very difficult. Therefore, it is important to develop effective procedures for identifying and locating SMEs who are capable of providing realistic estimates of the types and amounts of resources required for providing training on rarely performed TTMs.

Similarly, in the resource availability data collection, considerable difficulty was experienced in obtaining SME judgments about training resource availability for a substantial portion of the TTC courses, FTD courses, and operational units associated with a specialty. This difficulty was particularly troublesome because the representative sites for each specialty were determined primarily on the basis of data furnished by trainers of TTC and FTD courses and by senior noncommissioned officers from operational units.

To avoid even encountering such problems, it would be necessary to uncover suitable data for identifying representative sites in existing Air Force data sources. For example, the authorization data developed by the Military Personnel Center might be useful for this purpose, especially for operational units. More likely, it will be necessary to overcome such problems by developing and implementing effective procedures for increasing the percentages of TTC courses, FTD courses, and relevant operational units for which SMEs furnish judgments about resource availability. At a minimum, such procedures would doubtless include extensive follow-up efforts to encourage SMEs to complete and return questionnaires. Such follow-up efforts could include mail or telephone reminders, and announcements by superior officers urging cooperation.

9.2 Improved Data Collection Instruments and Procedures

Improvements can also be made to data collection instruments and procedures, including modifications of the content and format of questionnaires, revisions of associated instructions, and adjustments to the processing and interpretation of responses. For example, for the collection of data on resource requirements, a separate list of potentially required resources was developed for each individual TTM in an AFS. That list was then used to obtain SME estimates of the amounts of resources required for providing training on that TTM in any training setting. A small number of SMEs objected to the use of a single list of potentially required resources for all training settings. They asserted that, in many instances, a resource that is required for providing training on a particular TTM in one training setting would be unusable in another setting. A few SMEs even refused to respond to the Training Resource Requirements Questionnaire for this reason, stating that use of the same resource list for all training settings revealed misunderstanding of the essential nature of Air Force training. To avoid repetition of such problems, a separate list of resources potentially required for each TTM should be developed for each training setting.

The resource requirements data collection also involved some ambiguity as a result of incomplete SME responses to the data collection instruments. In particular, many SMEs did not provide estimates of the amounts required for all of the resources listed for each TTM and training setting. Typically, the SMEs left the corresponding fields on the questionnaire blank. The proper interpretation of those blank fields is not obvious. A blank field might indicate that the SME believes that the associated resource is not required for providing training on that TTM in that training setting; or it might indicate that the SME believes that the resource is required, but is unable to furnish a judgment about the amount. To avoid such ambiguities, instructions should be prepared directing SMEs to make the meanings of all their entries explicit. Suitable qualitative responses should be developed to distinguish between the situations described above and, as appropriate, among other analogous situations.

Ambiguity also arose whenever an SME reported that a resource that was not listed in the questionnaire was actually required for conducting training on a particular TTM in a particular training setting. It is not clear under these circumstances whether the other SMEs who furnished judgments about resource requirements for the same TTM and training setting would agree that the unlisted resource was required for that training, or whether they would oppose adding that resource to the list. To resolve this source of ambiguity, explicit procedures should be developed for processing and interpreting any SME judgments that unlisted resources are required for the

provision of training. For example, opinions about such judgments might be solicited from other SMEs who provided resource requirement estimates for the same TTMs and training settings, and independent estimates of requirements for the unlisted resources might be requested from those SMEs, as appropriate.

Ambiguity in SME responses also affected the collection of data on resource availability. As in the resource requirements data collection, many SMEs did not provide estimates for all of the resources listed on the Resource Availability Questionnaire and, instead, left the corresponding fields blank. Once again, blank fields can reasonably be interpreted in more than one way. For example, a blank field might indicate that the corresponding resource is never available, that it is always available, or that it normally is sufficiently available that the SME has never considered the possibility that its availability might be too limited for some plausible alternative U&T patterns. Obviously, the capacity of the associated course or operational unit to conduct training could vary substantially depending upon which interpretation is correct.

A somewhat different form of ambiguity arose in some situations where SMEs clearly believed that ample supplies of particular resources were always available for use in performing training. Specifically, instead of furnishing a quantitative estimate of the amount available, the SMEs wrote responses such as "lots," "gobs," and "infinite" in the fields associated with those resources on the questionnaire. Whenever such responses are provided, it is impossible to characterize the availability of the corresponding resources in terms of an arithmetic average. To avoid repetition of such ambiguities, instructions should be prepared directing SMEs to make explicit entries in all fields on the Resource Availability Questionnaire for all the resources listed. Suitable qualitative responses should be indicated for SMEs to use in all circumstances where they are unable to determine satisfactory quantitative estimates.

It is also important to recognize, however, that quantitative estimates of resource availability are not necessary within the TDS for any resources that are always available in ample quantities, and hence would never constrain the training capacity of any course or operational unit affiliated with the AFS. Since the only analytic use of resource availability data in the TDS is the evaluation of training capacity, such resources could be eliminated from the list in the Resource Availability Questionnaire without diminishing the analytic capabilities of the TDS in any way. In addition, reducing the length of that resource list would decrease the reporting burden imposed on respondents, which might stimulate cooperation from some SMEs who otherwise would have declined to respond. Thus, the Resource Availability Questionnaire for any specialty should be refined by developing, in collaboration with knowledgeable SMEs, an abbreviated list of resources that includes only those that

either have constrained training capacity in the current U&T pattern or might constrain training capacity in some plausible alternative U&T pattern.

In addition, when collecting resource availability data for TTCs and FTDs, it is important to account for any sharing of resources that routinely occurs among courses (including, possibly, courses affiliated with different AFSSs) at particular sites. Accordingly, the Resource Availability Questionnaires for TTC and FTD courses should be suitably revised to collect from SMEs all information necessary to evaluate the operative amounts of resources truly available for providing training in a particular course or set of courses. Procedures should also be developed for determining the appropriate source of information about the availability of resources that are shared by two or more courses. That source may vary among specialties and among locations within specialties, depending largely upon the degree to which resource procurement and utilization are centrally managed. If management is highly centralized, the resource manager for the training center might be the best source of information; in other situations, it might be necessary to accumulate estimates of amounts of resources available furnished by individual course instructors.

Analogously, in the collection of resource availability data for operational units, the principal issue to be resolved is how to account properly for the sharing of resources between training and operational uses. The primary refinement necessary in this regard is the development of suitable formats and procedures to account for the relationship between the number of shifts the unit operates during a typical day and the amount of time that resources are actually available for use in providing training while the personnel requiring the training are on duty.

Finally, after the refinements designed to eliminate ambiguities in the resource availability data collected from SMEs have been implemented, it will be possible to investigate alternative methods of summarizing the individual estimates furnished for the various operational and training units that are associated with particular representative sites. Due to the various ambiguities in the data collected, the amount of each resource available at any representative site was calculated as the median of all non-zero estimates provided by SMEs for the operational units associated with that representative site. With the improved data collection instruments and procedures described above, more methods of synthesizing the data will become feasible. Accordingly, other data synthesis methods should be evaluated, and the method that attains the most meaningful and useful measurement of resource availability should be determined.

9.3 Expanded Cost Estimation

In the research summarized in this report, unit cost factors and associated total cost estimates were derived for only four general categories of costs: namely, the costs of trainer time, trainee time, travel, and subsistence or per diem (i.e., TDY costs). Ultimately, it would be desirable to develop unit cost factors for all resource uses involving annual recurring costs. Indeed, it might even be desirable eventually to derive unit cost factors for the capital costs of long-lived resources, including both equipment and facilities.

At the present time, however, it is recommended that unit cost factors should be developed for two additional categories of costs. First, unit cost factors should be derived for expendable resources (i.e., resources that are consumed through use during the routine delivery of training, such as ammunition used in weapon system qualification and proficiency training). The data required for their estimation should, in general, be available from existing Air Force sources.

The other cost category for which unit cost factors should be developed relates to the annual costs of operating and maintaining all long-lived resources (i.e., facilities and equipment) used in the provision of training in an AFS. Long-lived resources typically are not used exclusively for providing training on individual TTMs in individual AFSs. Rather, they commonly are shared among several TTMs, among different AFSs, and even between training and operational activities. Moreover, the nature and intensity of the uses to which specific resources are applied often vary markedly among those different circumstances. Accordingly, the portions of the annual costs of operating and maintaining particular long-lived resources that are attributable to specific training activities generally will differ substantially among resources and types of activities.

Thus, developing realistic estimates of the portions of the annual operating and maintenance costs of long-lived resources that are attributable to specific training activities will be considerably more complex than developing such estimates for other categories of costs. The costs of operating and maintaining long-lived resources can, however, be an important factor in determining the most cost-effective method of performing particular training activities.

Preliminary research relating to this topic is currently being conducted for resources used in TTCS. The research is being performed by ATC/ACC, and has derived estimates of aggregate operation and maintenance costs for resources used exclusively in the delivery of training. That research should be thoroughly reviewed and, based on the results of that review, techniques should be developed for extending the research to

permit estimation of unit cost factors relating to the use of specific types of long-lived resources in providing training on specific TTMs in specific training settings.

Furthermore, for all of the modifications and extensions to the RCS discussed above, alternative methods of accomplishing the refinements should be devised and evaluated. Trial applications of the alternative methods should be conducted, as appropriate, and their comparative performance should be appraised, both quantitatively in terms of the empirical outcomes, and qualitatively in terms of their operational characteristics. Finally, based on the results of the appraisals, decisions about the implementation of the various alternatives should be made.

REFERENCES

Christal, R.E. (1974). The United States Air Force occupational research project (AFHRL-TR-73-75, AD-774574). Lackland AFB, TX: Personnel Research Laboratory, Aerospace Medical Division.

Cooper, R., & Kaplan, R.S. (1988, September-October). Measure costs right: Make the right decisions. Harvard Business Review, 66, 96-103.

Department of the Air Force. (1986). USAF formal schools (AFR 50-5). Washington, DC.

Horngren, C.T. (1982). Cost accounting: A management emphasis (5th ed.) Englewood Cliffs, NJ: Prentice-Hall, Inc.

Kaplan, R.X. (1982). Advanced management accounting (1st ed.). Englewood Cliffs, NJ: Prentice-Hall, Inc.

Kaplan, R.S. (1983, October). Measuring manufacturing performance: A new challenge for management accounting research. Accounting Review, 58, 686-705.

Kaplan, R.S. (1986). The role for empirical research in management accounting. Accounting, Organizations and Society, 11, 429-452.

Kaplan, R.S. (1988, January-February). One cost system isn't enough. Harvard Business Review, 66, 61-66.

Klemstine, C., & Maher, M. (1983). Management accounting research: 1929-1983. Sarasota, FL: American Accounting Association, Management Accounting Section.

Monthly military basic rates of pay (1987, May). Air Force Magazine, 70, 82.

Perrin, B.M., Knight, J.R., Mitchell, J.L., Vaughan, D.S., & Yadrick, R.M. (1988). Training decisions system: Development of the task characteristics subsystem (AFHRL-TR-88-15, AD-A199 094). Brooks AFB, TX: Air Force Human Resources Laboratory, Training Systems Division.

Rueter, F.H., Feldsott, S.I., Casper, H., Marshall, G.A., & Vaughan, D.S. (1988a). The resource cost subsystem -- task III administrative report: 305X4. Pittsburgh, PA: CONSAD Research Corporation.

Rueter, F.H., Feldsott, S.I., Casper, H., Marshall, G.A., & Vaughan, D.S. (1988b). The resource cost subsystem -- task III administrative report: 328X4. Pittsburgh, PA: CONSAD Research Corporation.

Rueter, F.H., Feldsott, S.I., Casper, H., Marshall, G.A., & Vaughan, D.S. (1988c). The resource cost subsystem -- task III administrative report: 423X1. Pittsburgh, PA: CONSAD Research Corporation.

Rueter, F.H., Feldsott, S.I., Casper, H., Marshall, G.A., & Vaughan, D.S. (1988d). The resource cost subsystem -- task III administrative report: 811XX. Pittsburgh, PA: CONSAD Research Corporation.

Thomas, A.L. (1974). The allocation problem: Part two (Studies in accounting research No. 9). Sarasota, FL: American Accounting Association.

Tompkins, C., & Groves, R. (1983). The everyday accountant and researching his reality. Accounting, Organizations and Society, 8, 361-374.

Turney, P.B.B. (1989, Summer). Using activity-based costing to achieve manufacturing excellence. Journal of Cost Management, 3, 23-31.

ACRONYMS AND ABBREVIATIONS

ABGD	Air Base Ground Defense
ABR	Prefix for Airman Basic Resident courses
AFB	Air Force Base
AFHRL	Air Force Human Resources Laboratory
AFR	Air Force Regulation
AFS	Air Force Specialty
ATC	Air Training Command
ATC/ACC	Cost Analysis Directorate of the Air Training Command
AWACS	Airborn Warning and Control System
CDC	Career Development Course
CODAP	Comprehensive Occupational Data Analysis Programs
CONUS	Continental United States
ESM	Environmental Systems Management
FTD	Field Training Detachment
FUS	Field Utilization Subsystem
IOS	Integration and Optimization Subsystem
MTT	Mobile Training Team
MWD	Military Working Dog
OJT	On-the-Job Training
OSR	Occupational Survey Report
PME	Professional Military Education
RAF	Royal Air Force
RCS	Resource Cost Subsystem
SAC	Strategic Air Command
SEI	Special Experience Identifier
SME	Subject-Matter Expert
TAC	Tactical Air Command
TAF	Tactical Air Forces
TCS	Task Characteristics Subsystem
TDS	Training Decisions System
TDY	Temporary Duty
TTC	Technical Training Center
TTM	Task Training Module
U&T	Utilization and Training
USAF	United States Air Force

GLOSSARY OF TERMS

representative site:	a model of a hypothetical Air Force unit used as a characterization of several similar actual operational or training units.
resources:	labor, materials, equipment and facilities used in the provision of training in a specialty. Resources can include: classroom and laboratory space, time allotted to training by trainers and training supervisors, media aids, course material, school and base support equipment and facilities, time expended by trainees in completing routine and remedial training, and materials and equipment used in traveling to and from training sites.
site:	an Air Force operational or training unit to which personnel in a specialty are assigned.
training setting:	a generic means of delivering training, such as classroom instruction, self-paced individual study (e.g., through written materials or computer-based instruction), hands-on training, and supervised hands-on experience on the job.
training state:	a set of specific amounts of time allotted to training specific TTMs in particular training settings to a distinct group of personnel at a site.
training volume:	the number of personnel requiring training on particular TTMs for specific amounts of time.

APPENDIX A: TRAINING CAPACITY MEASUREMENT

The capacity of the Air Force to perform the types and amounts of training required for any particular U&T pattern can be evaluated using two basic methods. These are the ratio method and the mathematical programming method.

1.0 Data Requirements

Both methods rely on the same fundamental data. Specifically, for any U&T pattern, these data consist of:

$A(i,s)$ = the amount of resource i available for the provision of training at site s ($i=1, \dots, n$; and $s=1, \dots, M$);

$GR(i,j,k)$ = the amount of resource i required for providing concurrent instruction on TTM j to a group of trainees in setting k ($i=1, \dots, n$; $j=1, \dots, m$; and $k=1, \dots, q$);

$GN(t)$ = the number of trainees per group in training state t ($t=1, \dots, T$);

$IR(i,j,k)$ = the amount of resource i required per trainee for providing individual training on TTM j in setting k ($i=1, \dots, n$; $j=1, \dots, m$; and $k=1, \dots, q$); and

$N(t,s)$ = the number of trainees requiring training in training state t at site s per time period ($s=1, \dots, M$; and $t=1, \dots, T$).

Then $R(i,t)$

= $\sum_{j,k \in t} [GR(i,j,k)/GN(t)] + IR(i,j,k)$

= the total amount of resource i required per trainee for providing training in training state t [i.e., for providing the proportion of training specified for each TTM j allocated to the setting(s) k associated with training state t],

and $TR(i,s)$

= $\sum_{t=1}^T N(t,s) \cdot R(i,t)$

= the total amount of resource i required per time period for the provision of training (in all training states, and hence for all TTMs and in all settings) at site s .

The use of these data to measure training capacity with the ratio method and the mathematical programming method is described in Sections 2.0 and 3.0 below.

2.0 The Ratio Method

In the ratio method, the capacity of the Air Force to perform training is evaluated on the basis of ratios of the amounts of particular resources available for the provision of training and the amounts of those resources required for training. More precisely, the capacity of resource i to support the training required at site s in any particular U&T pattern p can be measured as:

$$KR(i,s) = \begin{cases} A(i,s)/TR(i,s) & \text{if } TR(i,s) > 0 \\ 0 & \text{otherwise} \end{cases}$$

Whenever the ratio calculated for any resource is less than 1.0, the amount of that resource available for the provision of training at that site is insufficient to support the total amount of training required at the site in that U&T pattern. However, because this measure is based on input use and not on output production, it does not have a unique, unambiguous relationship to the proportion of the total number of trainees at site s who are actually trained to the proportions of full proficiency specified for the TTMs for which resource i is used in the U&T pattern. The amounts of resource i required per trainee can vary substantially across the training states (i.e., the particular combinations of TTMs and settings) associated with the groups of trainees at site s who are entering specific jobs in the U&T pattern. Consequently, when $KR(i,s)$ is less than 1.0, the proportion of the total number of trainees whose training requires resource i which could be accommodated by the available quantity of the resource could be substantially larger than $KR(i,s)$ if there are notable differences in the total amounts of resource i required for the provision of training on the entire sets of TTMs on which different groups of trainees require training. (This result could be achieved, for example, by allocating the available amount of resource i among the various groups of trainees in increasing order of the amounts of the resource required per trainee for those groups.) In addition, the measure $KR(i,s)$ does not consider the relative importance to the Air Force of providing training to the various groups of trainees who need training on the TTMs for which the resource is required.

However, if the total amounts of resource i required for the provision of training are sufficiently similar for the different groups of trainees requiring training for which the resource is needed, $KR(i,s)$ can reasonably be interpreted as the maximum proportion of the trainees in those groups at site s who can be provided the proportions of training specified for the TTMs for which resource i is required. Then:

$$KN(i,s) = KR(i,s) \sum_{t=1}^T N(t,s)$$

$R(i,t) > 0$

= the maximum number of trainees per time period to whom training that requires resource i can be provided at site s with the amount of resource i available at that site,

$$\text{and } \tilde{KN}(i,s) = \begin{cases} [1-KR(i,s)] \sum_{t=1}^T N(t,s) & \text{if } KR(i,s) < 1 \\ R(i,t) > 0 \\ 0 & \text{otherwise} \end{cases}$$

= the minimum number of trainees per time period to whom training that requires resource i cannot be provided at site s because of the limited availability of resource i at that site.

Moreover, as explained in Sections 2.1 and 2.2 below, if the interpretation of $KR(i,s)$ stated above is reasonable for all resources required for training at the site, the capacity of site s to support the training required at the site in that U&T pattern can be estimated on the basis of $\tilde{KN}(i,s)$ for $i=1, \dots, n$.

2.1 Upper Bound Estimate of Training Capacity

To develop an upper bound estimate of the capacity of a site to provide the amount of training required per time period with any U&T pattern, it is first necessary to recognize that a lower bound estimate of the number of trainees per time period to whom training cannot be provided at site s due to limited resource availability can be expressed as:

$$\tilde{K}(s,L) = \text{Maximum } \tilde{KN}(i,s).$$

i

$\tilde{K}(s,L)$ represents a lower bound estimate because it is possible that, for some resource other than the resource i for which

$\tilde{K}(i,s)$ is largest, it may not be feasible to arrange training so that only trainees to whom training cannot be provided due to limited availability of resource i are among those to whom training is not provided as a result of the limited availability of the other resource. Whenever such a training arrangement cannot be accomplished, the actual number of trainees to whom training cannot be provided at site s due to limited resource availability will be greater than $\tilde{K}(s,L)$.

Nevertheless, whenever $\tilde{K}(s,L)$ is considered to be a reasonable approximation to that actual number, an upper bound estimate of the capacity of site s to provide the required amount of training per time period can be expressed as:

$$K(s,U) = \sum_{t=1}^T N(t,s) - \text{Maximum}_i \tilde{K}(i,s)$$

$$K(s,U) = \text{Minimum}_i [\sum_{t=1}^T N(t,s) - \tilde{K}(i,s)].$$

Moreover, even under these circumstances, this measure can substantially understate the capacity of the site to provide training because it does not consider the possibility that surplus resources of one type might be substituted for scarce resources of another type, at least in some TTMs. Such substitution would increase the number of trainees who can be trained to the specified levels of proficiency with the total inventory of available resources.

2.2 Lower Bound Estimate of Training Capacity

A lower bound estimate of the capacity of a site to provide the amount of training required with any U&T pattern can be developed in a similar manner. Thus, an extreme upper bound estimate of the number of trainees per time period to whom training cannot be provided at site s due to limited resource availability can first be developed on the basis of $\tilde{K}(i,s)$ for $i=1, \dots, n$. Specifically:

$$\tilde{K}(s,U) = \sum_{i=1}^n \tilde{K}(i,s)$$

$\tilde{K}(s,U)$ represents an extreme upper bound estimate because it implicitly assumes that it is impossible to arrange training so that any trainee to whom training cannot be provided due to limited availability of any one resource corresponds to a trainee to whom training cannot be provided due to limited availability of some other resource. Thus, in essence, this measure assumes

that totally different types of resources are insufficiently available to each distinct group of trainees, and hence that it is impossible to relieve the consequences of limited resource availability by concentrating or accumulating unavoidable training deficiencies within a relatively small number of trainees.

Whenever this strong assumption of total resource inflexibility is considered acceptable, however, an extreme lower bound estimate of the capacity of site s to provide the required amount of training per time period can be expressed as:

$$K(s,L) = \sum_{t=1}^T N(t,s) - \sum_{i=1}^n \tilde{K}N(i,s).$$

As with the upper bound estimate of training capacity developed earlier, this measure of training capacity can substantially underestimate the capacity of a site to provide training because it too does not consider the possibility of substituting surplus resources of one type for scarce resources of another type.

2.3 Aggregate Estimates of Training Capacity

If the capacity of each site to support the amount of training required at that site per time period in a U&T pattern can be measured adequately in terms of $K(s,U)$ and/or $K(s,L)$ as defined above, the total capacity of the Air Force to support the training required for that U&T pattern can be estimated as:

$$TK(U) = \sum_{s=1}^M K(s,U) \text{ and/or } TK(L) = \sum_{s=1}^M K(s,L)$$

where M = the total number of sites in the Air Force.

Moreover, if sites are delineated such that each site is associated with a single major command, the total capacity of each major command to support the training required in that major command with that U&T pattern can be measured as:

$$MK[M(r),U] = \sum_{s \in M(r)} K(s,U) \text{ and/or } MK[M(r),L] = \sum_{s \in M(r)} K(s,L)$$

where $M(r)$ = the sites affiliated with major command r .

Such a delineation of sites requires that locations where units from different major commands are stationed must be represented as two or more sites. Such a representation is

reasonable provided no appreciable sharing of the resources required for training occurs among units from different major commands at any location. (Indeed, it is reasonable to designate as separate sites any units, or groups of units, that do not share resources required for training with any other units, or groups of units, to an appreciable extent -- even if the units, or groups of units, are affiliated with the same major command.)

As this measurement procedure emphasizes, capacity is an attribute of a site. Excess capacity at one site cannot normally be used to augment the capacities of other sites to provide training. (At a minimum, normal operating procedures must be modified to permit sharing of resources.) In the most general case, a different resource will determine the training capacity of each site. Thus, opportunities to augment training through substitution of less scarce resources for more scarce resources must be investigated initially for individual sites. The increments in capacity achieved for individual sites through resource substitution can then be aggregated to determine the total increments in capacity achieved for major commands and for the entire Air Force.

3.0 The Mathematical Programming Method

Mathematical programming provides a means for directly considering the feasibility of arranging training such that the people to whom training is not provided due to the limited availability of one resource are among those to whom training is not provided when adapting to the limited availability of another resource. To the degree that such opportunities are exercised, the number of people who are trained to full proficiency on all TTMs required for the accomplishment of a U&T pattern will be increased.

3.1 Maximization of Total Amount of Training

By maximizing the degree to which any unavailability of training resources is concentrated on a restricted group of trainees, the number of people trained to full proficiency on all required TTMs can be correspondingly maximized. This situation can be represented mathematically as:

$$\begin{aligned} \text{Maximize} \quad & \sum_{t=1}^T Q(t,s) \\ \text{subject to} \quad & Q(t,s) \leq N(t,s) \\ & \text{for } t=1, \dots, T \text{ and } s=1, \dots, M, \end{aligned}$$

$$\sum_{t=1}^T R(i,t) \cdot Q(t,s) \leq A(i,s)$$
 for $i=1, \dots, n$ and $s=1, \dots, M$,

and

$$Q(t,s) \geq 0$$
 for $t=1, \dots, T$ and $s=1, \dots, M$,

where

$$Q(t,s) =$$
 the number of trainees actually trained to full proficiency in training state t , per time period at site s .

In this formulation, the first constraining condition, $Q(t,s) \leq N(t,s)$, assures that no training in excess of requirements will be conducted in any training state at any site; and the second constraining condition, $R(i,t) \cdot Q(t,s) \leq A(i,s)$, assures that the training allocated to site s will not require resources in excess of the amounts available at the site. The final constraining condition, $Q(t,s) \geq 0$, precludes the unrealistic mathematical possibility of increasing the availability of resources at site s by providing negative training to certain people, and thereby releasing the resources required for their training for use in the training of others.

3.2 Maximization of Training Value

The formulation in Section 3.1 does not consider the relative importance or value to the Air Force of providing training to particular groups of trainees. However, if satisfactory measures of relative importance can be determined, the allocation of training resources that maximizes the total value obtained by the Air Force from the use of those resources can be estimated through mathematical programming. Specifically, this estimation can be expressed mathematically as:

Maximize
$$\sum_{t=1}^T V(t) \cdot Q(t,s)$$

subject to $Q(t,s) \leq N(t,s)$

$$\sum_{t=1}^T R(i,t) \cdot Q(t,s) \leq A(i,s)$$

and

$Q(t,s) \geq 0$ for all i , t , and s , as appropriate,

where

$$V(t) =$$
 the relative importance or value to the Air Force achieved by training the people in training state t to full proficiency.

Moreover, separate measures of relative importance, $V(t,s)$, could be established for each site. More generally, nonlinear preference functions could be specified that indicate varying patterns of relative importance for differing allocations of training among training states. This situation can be expressed mathematically as:

Maximize $U[Q(t,s); t=1, \dots, T \text{ and } s=1, \dots, M]$

subject to $Q(t,s) \leq N(t,s)$

$$\sum_{t=1}^T R(i,t) \cdot Q(t,s) \leq A(i,s)$$

and $Q(t,s) \geq 0$ for all i , t , and s , as appropriate,

where $U[Q(t,s); t=1, \dots, T \text{ and } s=1, \dots, M]$ is the Air Force preference function for the allocation of training among settings and sites.

Alternatively, if only ordinal preferences among training settings and sites can be developed, the optimal allocation of training and associated training resources can be determined using goal programming.

3.3 Extensions to Account for Discreteness in Resource Utilization

Certain types of resources may only be available or may only be permitted to be used in sizable discrete units. Such conditions appear particularly pertinent for resident technical training schools and, possibly, for FTDs. For example, Congress has mandated the 8-hour training day, which requires that resident technical training must be conducted for 8 full hours during each day of each course. This requirement implies that TTM's can be allocated to resident training schools only in combinations for which training can be accomplished in integer multiples of 8 hours. Thus, stated mathematically, the set of TTM's allocated to any resident technical training course must fulfill the condition:

$$\sum_{j,k \in t} T(j,k) = K \cdot 8$$

where $T(j,k) =$ the amount of time required for providing the proportion of training on TTM j allocated to setting k (for each TTM j allocated to the setting k associated with training state t), and

K = a non-negative integer (i.e., 0,1,2,3,...).

In addition, the substantial costs of transporting trainees to resident technical training school implies that courses taught in that setting should last some minimum number of days, D(k). Expressed mathematically, this condition is:

$$K \geq D(k).$$

In combination, the above conditions establish minimum incremental durations and minimum total durations, respectively, for courses in resident technical training schools and, as appropriate, other training settings. These conditions, in effect, require alternative feasible allocations of TTMs among training settings to differ in terms of sizable discrete distinctions.

Any of the formulations described above can be implemented using currently available computation technology. However, the more complex formulations require more extensive data bases, more intricate mathematical programming algorithms (i.e., goal programming, integer programming, and mixed integer-linear programming algorithms), and hence more time and resources for their implementation and operation. Accordingly, only the basic linear programming formulation of the mathematical programming method for estimating training capacity has currently been implemented.

APPENDIX B: TRAINING COST ESTIMATION

The annual variable costs that must be incurred by the Air Force in performing the types and amounts of training required for any particular U&T pattern can be estimated for different organizational levels, and in terms of both cost per trainee and total cost.

1.0 Data Requirements

For any U&T pattern, the data required for estimating annual variable training costs consist of:

$C(i)$ = the unit cost factor for resource i ($i=1, \dots, n$), i.e., the annual recurring expenditure on a unit of resource i ;

$GR(i,j,k)$ = the amount of resource i required for providing concurrent instruction on TTM j to a group of trainees in setting k ($i=1, \dots, n$; $j=1, \dots, m$; and $k=1, \dots, q$);

$GN(t)$ = the number of trainees per group in training state t ;

$IR(i,j,k)$ = the amount of resource i required per trainee for providing individual training on TTM j in setting k ($i=1, \dots, n$; $j=1, \dots, m$; and $k=1, \dots, q$); and

$N(t,s)$ = the number of trainees requiring training in training state t at site s per time period.

Then $R(i,j,t) = \sum_{k \in t} [GR(i,j,k)/GN(t)] + IR(i,j,k)$ for all $j \in t$

= the total amount of resource i required per trainee for providing training on TTM j in training state t [i.e., for providing the proportion of the training specified for TTM j that is allocated to each setting k associated with training state t].

The use of these data to estimate training cost per trainee and total training cost for various organizational levels is described in Sections 2.0 and 3.0 below.

2.0 Variable Training Cost Per Trainee

Starting at the most detailed level of cost estimation that will be achievable for a specific U&T pattern with the data routinely collected in the RCS, the annual variable cost per trainee associated with the use of a particular type of resource in providing the training on a specific TTM in a specific training state that is designated within the U&T pattern can be estimated as:

$$CV(i, j, t) = C(i) \cdot R(i, j, t)$$

= the annual variable cost incurred per trainee as a result of using the amount of resource i required per trainee for providing the proportion of training on TTM j allocated to training state t ($i=1, \dots, n$; $j=1, \dots, m$ and $j \in t$; and $t=1, \dots, T$).

Then, summing over the various types of resources, the aggregate annual variable cost per trainee incurred in providing the training on a specific TTM in a specific training state that is designated within a particular U&T pattern can be calculated as:

$$VCM(j, t) = \sum_{i=1}^n VC(i, j, t)$$

= the annual variable cost incurred per trainee in providing the proportion of training on TTM j allocated to training state t ($i=1, \dots, n$; $j=1, \dots, m$ and $j \in t$; and $t=1, \dots, T$).

Next, summing over all TTMs that are included in a particular training state, the annual variable cost per trainee associated with providing the training designated for that training state within the U&T pattern under consideration can be measured as:

$$VCS(t) = \sum_{j \in t} VCM(j, t)$$

= the annual variable cost incurred per trainee in providing the training allocated to training state t ($t=1, \dots, T$).

All of the above estimates of annual variable cost per trainee are independent of the number of trainees to whom the associated training is provided. Measures of annual variable cost per trainee can also be developed for other organizational levels (e.g., all training provided at a base, within a major command, or throughout the entire Air Force). However, the values computed for those measures will depend upon the relative numbers of trainees participating in the various training states at those organizational levels, and those values will change whenever the allocation of trainees among training states changes.

3.0 Total Annual Variable Cost

Because training resource requirements for each training state are directly proportional to the number of trainees receiving the corresponding training, estimation of the total annual variable cost of providing that training merely involves multiplying the annual variable cost per trainee for that training by the number of trainees receiving the training, and summing as necessary. Thus, the total annual variable cost of providing the training designated for a particular training state at a specific site within a particular U&T pattern can be estimated as:

$$TVCSL(t,s) = VCS(t) \cdot N(t,s)$$

= the total annual variable cost incurred in providing the training allocated to training state t at site s ($t=1, \dots, T$; and $s=1, \dots, M$).

Further, summing over sites, the total annual variable cost of providing all of the training designated for a particular training state throughout the Air Force within that U&T pattern can be calculated as:

$$TVCS(t) = VCS(t) \sum_{s=1}^M N(t,s)$$

= the total annual variable cost incurred in providing all training allocated to training state t ($t=1, \dots, T$).

Then, summing over training states, the total annual variable cost of providing all training designated within the U&T pattern can be measured as:

$$TVC = \sum_{t=1}^T TVCS(t)$$

= the total annual variable cost incurred in providing all required training.

Similarly, if sites are delineated such that each site is associated with a single major command, the total annual variable cost of providing the training designated for a particular training state within a specific major command in that U&T pattern can be calculated as:

$$TVCMS(t) = VCS(t) \sum_{s \in M(r)} N(t,s)$$

= the total annual variable cost incurred in providing all training allocated to training state t in major command r ($t=1, \dots, T$).

Summing over all training states, the total annual variable cost of providing all training indicated for that major command within the U&T pattern can then be estimated as:

$$TVCM = \sum_{t=1}^T TVCMS(t)$$

= the total annual variable cost incurred in providing all training indicated for major command r .

In a similar manner, estimates of total annual variable costs can be derived for individual sites, for particular combinations of training states (e.g., all training states involving a specific training setting), for a particular resource type or combination of resource types, or for any combination of the various degrees of detail. All such estimates merely involve calculating the sum of the products of appropriate annual variable costs per trainee and corresponding numbers of trainees.

APPENDIX C: DATA COLLECTION INSTRUMENTS FOR IDENTIFICATION
OF TYPES OF RESOURCES REQUIRED FOR TRAINING

Two basic forms of data collection instruments were developed to obtain information from SMEs concerning the types of resources required for the provision of training on the individual TTMs in a particular AFS. The first form applies to specialties for which it was feasible to compile preliminary lists of potentially required resources for the individual TTMs of the specialty based on information that is routinely reported in standard Air Force documents (AFSs 328X4, 423X1 and 811XX); and the second form applies to AFS 305X4, for which preliminary lists of potentially required resources could be compiled only for the specialty as a whole. Sample instructions for the first form of data collection instrument are contained in Section 1.0 of this appendix, and the instructions for the second form are presented in Section 2.0.

1.0 Data Collection for Specialties with Preliminary Resource Lists for Individual TTMs

INSTRUCTIONS FOR SMEs ASSISTING IN IDENTIFYING THE TYPES OF RESOURCES REQUIRED FOR TRAINING IN AFS 328X4

Background and General Instructions

In order to estimate (a) the cost of conducting training on the individual 328X4 task training modules (TTMs) in the various training settings (classroom, OJT, etc.) and (b) the capacity of individual sites to support that training, it is first necessary to identify the specific types of resources required for the training. We would appreciate your help in developing a list of those types of resources.

Preliminary lists of the types of equipment that might be required for each TTM have been developed on the basis of lists of the tasks included in the 328X4 TTMs, the lists of equipment contained in the January 1983 USAF Job Inventory for the avionic inertial and radar navigation systems career ladders, the plan of instruction from Keesler Technical Training Center, and the judgments of a recently retired 328X4 SME. The accompanying packet of materials contains, for each TTM, both the list of tasks included in the TTM and the preliminary list of types of equipment for that TTM. A copy of the complete list of equipment from the 328X4 job inventory is included at the back of this packet.

We would like you to refine preliminary lists of equipment that might be required to provide training on TTMs. Please add and/or delete items as appropriate in order to develop a final list of equipment that is actually needed to train each of the TTMs.

In the preliminary lists, a piece of equipment has been judged to be required for a TTM when either:

1. The piece of equipment is specifically mentioned in one or more of the tasks included in the TTM, or
2. Because of the nature of the tasks in the TTM, the piece of equipment appears necessary for performing one or more of those tasks.

Since the latter criterion has been employed in many instances, there is some uncertainty about whether particular types of equipment are actually needed for performing training on a TTM.

In addition, some types of equipment have not been associated with any TTMs, because either the precise nature or the use of that type of equipment is unclear to us. These items are designated by the symbol "*" on the full list of equipment found at the back of this packet.

In the preliminary lists, types of equipment have been associated with TTMs on the basis of their pertinence to the performance of one or more of the tasks in the TTM. However, an item required for the performance of a task may not be needed for the provision of training on the task. Conversely, some types of resources may be required for training, although they are not needed for the performance of operational duties. Please keep in mind that we are concerned primarily with the provision of training as you add and delete items from the preliminary lists. The list of equipment from the job inventory has been included at the back of this packet to assist you in this activity. You are also urged to indicate any additional types of resources that you believe are needed for the provision of training in any TTM, paying particular attention to training aids (e.g., projectors, VCRs, etc.). Please indicate all such changes directly on the preliminary lists of resources included in the packet.

Specific Instructions

For each task training module, after examining the list of tasks included in the module and the preliminary list of equipment required for training the task module:

1. Delete from the list any items that are not required for training the task module. You can accomplish this by simply crossing out the item on the list.
2. Add to the list any item that is required for training the task module and is not included in the preliminary list. Please give particular consideration to the items designated by the symbol "*" found in the full list of equipment at the back of the packet.
3. Indicate equipment items that are generally used together in the provision of training. An obvious example of this is a projector and screen.

Thank you for your assistance with this important activity.

If you have any questions or problems, please call Steve Feldsott or Fred Rueter at Area Code 412, telephone number 363-5500; call collect.

2.0 Data Collection for Specialties with Preliminary Resource Lists Only for the Specialty as a Whole

INSTRUCTIONS FOR SMEs ASSISTING IN IDENTIFYING THE TYPES OF RESOURCES REQUIRED FOR TRAINING IN AFS 305X4

Background and General Instructions

In order to estimate (a) the cost of conducting training on the individual 305X4 task training modules (TTMs) in the various training settings (classroom, OJT, etc.) and (b) the capacity of individual sites to support that training, it is first necessary to identify the specific types of resources required for the training. We would appreciate your help in developing a list of those types of resources.

This package of material contains the list of tasks included in each of the TTMs and a copy of the list of equipment contained in the April 1982 USAF Job Inventory for the electronic computer and switching systems career ladder.

We would like you to develop lists of the equipment that might be required to provide training on these TTMs. Please list items as appropriate in order to develop a final list of equipment that is actually needed to train each of the TTMs.

Please keep in mind that we are concerned primarily with the provision of training as you specify items from the list of equipment. The list of equipment has been included at the back of this packet to assist you in this activity. You are also urged to indicate any additional types of resource not included in the list of equipment that you believe are needed for the provision of training in any TTM, paying particular attention to training aids (e.g., projectors, VCRs, etc.).

Specific Instructions

For each task training module, after examining the list of tasks included in the module and the list of equipment, please:

1. Develop a list of the equipment items that are required for training the task module.
2. Indicate equipment items that are generally used together in the provision of training. An obvious example of this is a projector and screen.

Thank you for your assistance with this important activity.

If you have any questions or problems, please call Steve Feldsott or Fred Rueter at Area Code 412, telephone number 363-5500; call collect.

APPENDIX D: DATA COLLECTION INSTRUMENTS FOR ESTIMATION OF AMOUNTS OF RESOURCES REQUIRED FOR TRAINING

Two basic forms of data collection instruments were developed to obtain from SMEs their estimates of the amounts of specific types of resources that are required for the provision of training on the individual TTMs in a particular AFS. The first form was used to collect such information from SMEs assigned to operational units, and the second form was used to obtain such estimates for individual courses from SMEs stationed as instructors at Technical Training Centers and Field Training Detachments. An example of the first form of data collection instrument is contained in Section 1.0 of this appendix, and an example of the second form is presented in Section 2.0.

1.0 Data Collection from SMEs Assigned to Operational Units

DATA COLLECTION INSTRUMENT FOR ESTIMATION OF AMOUNTS OF RESOURCES REQUIRED FOR TRAINING

Purpose/General Instructions

On an earlier questionnaire you provided estimates of the total amounts of time required to provide training on task training modules (TTMs) contained in this booklet in each of four training settings (classroom instruction, supervised hands-on, self-paced individual study, and on-the-job training). Those estimates included both current and ideal training times, which were defined as follows:

1. Current Training Time is the time you believe is currently devoted to reach minimum standards for a given group of tasks (task training module). This is for training to minimum standards only and does not mean expert or highly skilled performance. In terms of the GO/NO GO concept this is training up to the GO level only.
2. Ideal Training Time is the time you believe should be devoted to reach minimum standards in the most effective way. Making the most effective use of each type of training may involve providing more of some types of training and less of others. Or it may involve keeping the same levels as the current training system.

Now, within the context of your earlier training time estimates, we would like you to provide estimates of the amounts of time that specific resources are required to provide training in individual TTM's for the training settings with which you are familiar. Feel free to revise the earlier training time estimates, as appropriate. Please turn to the example on page 3 as you read the detailed instructions which follow. If, after reading the instructions and examining the sample responses, you are still unsure about how to proceed, please call Captain Joe Filer at AV 240-3047 (or call Steve Feldsott or Fred Rueter at Area Code 412, telephone number 363-5500; call collect).

Specific Instructions

The accompanying packet of materials contains, for each TTM, (a) a list of the tasks included in the TTM, (b) for each training setting, a list of resource items (equipment, weapons, training materials, trainer time) that may be required for the provision of training on that TTM, and (c) your estimates of the total amounts of time devoted to training that TTM (for both current and ideal training) in that training setting.

FOR THE TYPE OF TRAINING INDICATED ABOVE AND FOR THE GROUP OF TASKS ON THE OPPOSITE PAGE, PLEASE INDICATE THE FOLLOWING RESOURCE-SPECIFIC INFORMATION:

Column A	B	C	D	E	F	G	H	Current Training: 15 Hours				Ideal Training: 10 Hours			
								Number of hours each trainee must spend working with resource item.	If resource item is shared, indicate the maximum number of trainees that can effectively share the resource simultaneously.	If resource item requires instructor demonstration time, indicate number of instructor demonstration hours required.	Number of hours each trainee must spend working with resource item.	If resource item is shared, indicate the maximum number of trainees that can effectively share the resource simultaneously.	If resource item requires instructor demonstration time, indicate number of instructor demonstration hours required.	10 Hours	10 Hours
- Trainer 3305 Fighter Air Conditioning	6	-	.5	4	-	-	-							.5	0
- Trainer 2518 Bomber Air Conditioning Systems	6	-	.5	4	-	-	-							.5	0
- Multimeter	2	2	.25	0	2	2	-							-	10
- Bleed Air Lost Testers	2	3	.25	1	1	3	-							.25	8
- CTK	2	2	-	2	2	2	-							-	5
- Aircraft	0	-	-	0	-	-	-							-	never

The "zeroes" indicate that you would always use the trainers to train this TM in the classroom training setting. The "10", "8", and "5" indicate that classroom training would have to be reduced to these levels before you would stop using the multimeter, bleed air loss tester and CTK. The "never" indicates that you would never use the airplane in the classroom setting no matter how the time allowable for training in the classroom setting is expanded.

In your concept of ideal training, the multimeter would not be utilized in the classroom training setting.

Note that your trainee and instructor demonstration time estimates in columns B and D can sum to more than the total amount of time devoted to training a TM in a particular training setting. This can happen when resource items are used simultaneously.

Current Training	Ideal Training
Instruction (including time working with resources)	12.5
Preparation/Administration (if known)	5
Total trainee time (including preparation)	18

Total instructor time for:

Instruction (including time working with resources)

12.5

Preparation/Administration

5

Total trainee time (including preparation)

18

4

12.5

For each task module and each training setting for which you provided training time estimates, we would like you to provide information about the amount of time (in hours) that each resource item (listed in Column A) must be used for the provision of training on that TTM in that setting. Your responses should describe the amount of time that each trainee must actually spend working with each resource item (not the calendar time during which the resource item must be available). Separate estimates are needed for both current training (Column B) and ideal training (Column E). Please be certain that your time estimates make sense in terms of the total amount of time you allocated for the training of that TTM in that setting (e.g., the total amount of time for which a unit of any resource item is required for a particular TTM and training setting should not exceed the total amount of time allocated for training of that TTM in that setting). The hypothetical responses in Columns B and E of the example indicate estimated numbers of hours that each trainee must actively spend working with each of the resource items for current and ideal training.

For resource items that must be shared among the trainees, please indicate the maximum number of trainees that can effectively share one of those items simultaneously. Your responses should appear in Column C for current training and Column F for ideal training. In the example, the multimeter, bleed air loss testers and CTK are shared by the trainees in both current (Column C) and ideal (Column F) training.

In situations where the instructor first demonstrates the use of a particular type of resource, please indicate the number of instructor demonstration hours required in addition to the number of hours that each trainee must spend working with the resource item. Your responses should appear in Column D for current training and Column G for ideal training. In the example, instructor demonstration times range from 15 minutes to $\frac{1}{2}$ hour.

Certain resource items might only be used in the provision of training if enough total time were available to use them effectively. For such resource items, if the item is currently used in the provision of training for a given TTM and training setting, to what level would the total time allotted for training the TTM in that setting have to be reduced before you would stop using that resource item? A response of zero would indicate that you would always want to use that resource in that training setting. Conversely, if a resource item is not currently used in the provision of training for a given TTM and training setting, to what level would the total training time for the TTM in that setting have to be increased before you would begin to use the resource item? In the latter case, it is quite possible that you would never use a particular resource item to provide training for a given TTM in a particular training setting. If this is the case, simply respond "never." Your responses should appear in Column H.

Finally, for each task training module and training setting, indicate the total amount of time the instructor must spend (a) working with the trainees (both individually and in groups), and (b) preparing for training the TTM and performing administrative functions related to the TTM (if known). Also indicate the total amount of time (including preparation) that the trainee must spend in receiving training on each task module in each training setting. These estimates will not necessarily correspond directly to your estimates of the total amount devoted to the provision of training. For example, the amounts will be different if instructors are not actively involved in instruction during the entire time devoted to training (such as while students are practicing previously demonstrated techniques), if instructors spend time out of class on course preparation and administration, or if students spend time out of class on preparation or review. Separate estimates are needed for both current and ideal training. Your responses should appear in the spaces provided at the bottom of each page.

Again, if you have any questions or problems, please call Captain Joe Filer at AV 240-3047 or call Steve Feldsott or Fred Rueter, collect, at (412) 363-5500.

2.0 Data Collection from Instructors at Technical Training Centers or Field Training Detachments

INSTRUCTIONS FOR SUBJECT MATTER EXPERTS ASSISTING
IN ESTIMATING THE AMOUNTS OF RESOURCES REQUIRED FOR
TRAINING IN AFS 328X4 TECHNICAL TRAINING CENTERS/
FIELD TRAINING DETACHMENT COURSES

Purpose/General Instructions

In the Training Time Survey that you already completed, you provided estimates of the total amounts of time currently devoted to providing training on individual task training modules (TTMs) in each of three training settings (classroom instruction, supervised hands-on, and self-paced individual study) in a course for which you are responsible. Now, within the context of your earlier training time estimates, we would like you to provide estimates of the amounts of time that specific resources are required to provide training in individual TTMs for the three training settings. In addition, we would like you to indicate the total amounts of time that you believe should ideally be devoted to providing training on each TTM in each training setting in that course (including TTMs and settings not now contained in the course), and to estimate the amounts of time that specific resources would be required in conducting that training. Feel free to revise the earlier training time estimates, as appropriate.

Please turn to the example on page 3 as you read the detailed instructions which follow. If, after reading the instructions and examining the sample responses, you are still unsure about how to proceed, please call Captain Joe Filer at AV 240-3047 (or call Steve Feldsott or Fred Rueter at Area Code 412, telephone number 363-5500; call collect).

Specific Instructions

The accompanying packet of materials contains, for each TTM, (a) a list of the tasks included in the TTM, and (b) for each training setting, a list of resource items (equipment, weapons, training materials, trainer time) that may be required for the provision of training on that TTM.

For each task training module, we would first like you to record, in the space labelled "Current Training: hours" at the top of each table, the amount of training time that you reported on the Training Time Survey for that TTM and type of training. Next, in the space labelled "Ideal Training: hours," please indicate the total amount of time that you believe should ideally be devoted to providing that type of training on that TTM in your course. Provide estimates of ideal training times for any TTM that you believe should be included in the course, regardless of whether it is currently included.

TYPE OF TRAINING: Classroom instruction involving lecture/discussion and related reading
(most resident technical training).

FOR THE TYPE OF TRAINING INDICATED ABOVE AND FOR THE GROUP OF TASKS ON THE OPPOSITE PAGE, PLEASE INDICATE THE FOLLOWING RESOURCE-SPECIFIC INFORMATION:

Column A	B	C	D	E	F	G	H	Current Training: 15 Hours		Ideal Training: 10 Hours	
								Number of hours each trainee must spend working with resource item.	If resource item is shared, indicate the maximum number of trainees that can effectively share the resource simultaneously.	If resource item requires instructor demonstration time, indicate number of instructor demonstration hours required.	Number of hours each trainee must spend working with resource item.
- Trainer 3305 Fighter Air Conditioning	6	-	.5	4	-	.5	0				
- Trainer 2518 Bomber Air Conditioning System	6	-	.5	4	-	.5	0				
- Multimeter	2	2	.25	0	2	-	10				
- Bleed Air Lost Testers	2	3	.25	1	3	.25	8				
- CTK	2	2	-	2	2	-	5				
- Aircraft	0	-	-	0	-	-	never				
Note that your trainee and instructor demonstration time estimates in columns B and D can sum to more than the total amount of time devoted to training a TM in a particular training setting. This can happen when resource items are used simultaneously.								Total instructor time for:			
								Instruction (including time working with resources)	12.5	8	
								Preparation/Administration (if known)	5	4	
								Total trainee time (including preparation)	18	12.5	
								Current Ideal Training			
								Ideal Training			

The "zeroes" indicate that you would always use the trainers to train this TM in the classroom training setting. The "10", "8", and "5" indicate that classroom training would have to be reduced to these levels before you would stop using the multimeter, bleed air loss tester and CTK. The "never" indicates that you would never use the airplane in the classroom setting no matter how the time allowable for training in the classroom setting is expanded.

We would then like you to provide information about the amount of time (in hours) that each resource item (listed in Column A) must be used for the provision of training on that TTM in that setting. Your responses should describe the amount of time that each trainee must actually spend working with each resource item (not the calendar time during which the resource item must be available). Separate estimates are needed for both current training (Column B) and ideal training (Column E). Please be certain that your time estimates make sense in terms of the total amount of time you allocated for the training of that TTM in that setting (e.g., the total amount of time for which a unit of any resource item is required for a particular TTM and training setting should not exceed the total amount of time allocated for training of that TTM in that setting). The hypothetical responses in Columns B and E of the example indicate estimated numbers of hours that each trainee must actively spend working with each of the resource items for current and ideal training.

For resource items that must be shared among the trainees, please indicate the maximum number of trainees that can effectively share one of those items simultaneously. Your responses should appear in Column C for current training and Column F for ideal training. In the example, the multimeter, the bleed air loss testers, and the CTK are shared by the trainees in both current (Column C) and ideal (Column F) training.

In situations where the instructor first demonstrates the use of a particular type of resource, please indicate the number of instructor demonstration hours required in addition to the number of hours that each trainee must spend working with the resource item. Your responses should appear in Column D for current training and Column G for ideal training. In the example, instructor demonstration times range from 15 minutes to $\frac{1}{2}$ hour.

Certain resource items might only be used in the provision of training if enough total time were available to use them effectively. For such resource items, if the item is currently used in the provision of training for a given TTM and training setting, to what level would the total time allotted for training the TTM in that setting have to be reduced before you would stop using that resource item? A response of zero would indicate that you would always want to use that resource in that training setting. Conversely, if a resource item is not currently used in the provision of training for a given TTM and training setting, to what level would the total training time for the TTM in that setting have to be increased before you would begin to use the resource item? In the latter case, it is quite possible that you would never use a particular resource item to provide training for a given TTM in a particular training setting. If this is the case, simply respond "never." Your responses should appear in Column H.

Finally, for each task training module and training setting, indicate the total amount of time the instructor must spend (a) working with the trainees (both individually and in groups), and (b) preparing for training the TTM and performing administrative functions related to the TTM (if known). Also indicate the total amount of time (including preparation) that the trainee must spend in receiving training on each task module in each training setting. These estimates will not necessarily correspond directly to your estimates of the total amount devoted to the provision of training. For example, the amounts will be different if instructors are not actively involved in instruction during the entire time devoted to training (such as while students are practicing previously demonstrated techniques), if instructors spend time out of class on course preparation and administration, or if students spend time out of class on preparation or review. Separate estimates are needed for both current and ideal training. Your responses should appear in the spaces provided at the bottom of each page.

Again, if you have any questions or problems, please call Captain Joe Filer at AV 240-3047 or call Steve Feldsott or Fred Rueter, collect, at (412) 363-5500.

APPENDIX E: DATA COLLECTION INSTRUMENTS FOR ESTIMATION OF
AMOUNTS OF RESOURCES AVAILABLE FOR TRAINING

Two basic forms of data collection instruments were developed to obtain from SMEs their estimates of the amounts of specific types of resources that are available for the provision of training in a particular AFS at individual sites. The first form was used to collect such information for specific operational units from SMEs assigned to the units, and the second form was used to obtain such estimates for individual courses at particular Technical Training Centers and Field Training Detachments from the instructors of the courses. An example of the first form of data collection instrument is contained in Section 1.0 of this appendix, and an example of the second form is presented in Section 2.0.

1.0 Data Collection from SMEs Assigned to Operational Units

INSTRUCTIONS FOR BACKGROUND INFORMATION

In the spaces provided below, please fill in your name, social security account number, and base name and the information requested about your unit.

Name: _____

Social Security
Account Number: _____

Base: _____

Unit: _____

Aircraft Supported:

<u>Type</u>	<u>Number</u>
_____	_____
_____	_____
_____	_____
_____	_____

Amount of time available for the provision of OJT (i.e., giving training not receiving training) by members of your unit:

<u>Grade</u>	<u>Number of Airmen</u>	<u>Average Number of Hours Available to Each Airman Per Month for Conducting OJT</u>
E-2	_____	_____
E-3	_____	_____
E-4	_____	_____
E-5	_____	_____
E-6	_____	_____
E-7	_____	_____
E-8	_____	_____
E-9	_____	_____

Now turn to the next page and begin.

INSTRUCTIONS FOR SUBJECT MATTER EXPERTS ASSISTING
IN ESTIMATING THE AMOUNTS OF RESOURCES AVAILABLE
FOR ON-THE-JOB TRAINING USE IN AFS 328X4

In order to estimate the capacity of any individual operational unit to support OJT in AFS 328X4, it is necessary to determine the amounts of time that specific resources are available for use by the unit to support OJT in the specialty. We would like you to provide that information for your unit by completing the attached data collection form.

The data collection form contains a comprehensive list of the resource items (equipment, weapons, training materials) that various Air Force documents and the judgments of SMEs indicate are used in the provision of training in AFS 328X4. For each resource item (listed in Column A), please indicate (in Column B) the number of units of that resource item that typically are available for use by your unit in conducting OJT in AFS 328X4. Then, please indicate (in Column C) the number of hours, on average, that a unit of the resource item is available for use in providing OJT in the specialty during a typical day, week, or month. Please specify also, by circling the appropriate word in the heading of Column C, the time period (day/week/month) for which you have provided resource availability estimates.

If you have any questions or problems in completing the data collection form, please call Captain Joe Filer at AV 240-3407 (or call Steve Feldsott or Fred Rueter at Area Code 412, telephone number 363-5500; call collect).

Resource Item <u>A</u>	Number Available for Use in OJT in AFS 328X4	Hours Per Day/ Week/Month (Circle Relevant Time Period)	
		<u>B</u>	<u>C</u> Item is Avail- able for Use
039 Aircraft			
040 Antenna Simulator (NSA-90)			
005 AN/USM-74 Computer Test Sets			
041 Audio Oscillators			
042 Box Test Fixtures			
064 Chart Recorders			
069 Crystal Checkers			
070 Decade Dividers			
071 Decade Resistors			
073 Differential Voltmeters			
105 Digital Probes			
172 Digital Voltmeters			
074 Doppler Simulators			
077 Frequency Counters			
078 Frequency Meters			
083 Integrating Digital Voltmeters			
093 Load Simulators			
098 Meggers			
102 Microwave Test Lines			

2.0 Data Collection from Instructors at Technical Training Centers and Field Training Detachments

INSTRUCTIONS FOR SUBJECT MATTER EXPERTS ASSISTING IN
ESTIMATING THE AMOUNTS OF RESOURCES AVAILABLE FOR
USE IN AFS 328X4 TECHNICAL TRAINING CENTERS/
FIELD TRAINING DETACHMENT COURSES

In order to estimate the capacity of an individual Technical Training Center (TTC)/Field Training Detachment (FTD) to support training in AFS 328X4, it is necessary (a) to determine the amounts of time that specific resources are available for use in the individual courses conducted by the TTC, and (b) to identify the ways in which those resources are shared among courses and/or with operational activities. We would like you to provide that information for one of the courses for which you are responsible by completing the attached data collection form.

The data collection form contains a comprehensive list of the resource items (equipment, weapons, training materials, trainer time) that various Air Force documents and the judgments of SMEs indicate are used in the provision of training in AFS 328X4. For each resource item (listed in Column A), please indicate (in Column B) the number of units of that resource item that typically are available for use in the course under consideration. Then, please indicate (in Column C) the number of hours, on average, that a unit of the resource item is available for use in that course during a typical day, week, or month when the course is conducted. Please specify also, by circling the appropriate word in the heading of Column C, the time period (day/week/month) for which you have provided resource availability estimates.

Next, for each resource item used in the course under consideration, please identify (in Column D) the course number of all other courses conducted in the TTC/FTD with which the resource item is shared. Consider a resource item shared if the same units of the item are used in both courses, regardless of whether the use occurs during the same time period or in different periods. Finally, please indicate (with a check in Column E) whether each resource item used in the course is shared with any operational activities.

If you have any questions or problems in completing the data collection form, please call Captain Joe Filer at AV 240-3407 (or call Steve Feldsott or Fred Rueter at Area Code 412, telephone number 363-5500; call collect).

Resource Item	Hours Per Day / Week/Month (Circle Relevant Time Period) Item is Available for Use in Course	Other FTD Courses With Which Item is Shared	Item is Shared With Operational Activities (Check if Applicable)
A	B	C	D
Aircraft			E

Antenna Simulator (NSA-90)

AN/USM-74 Computer Test Sets

Audio Oscillators

Box Test Fixtures

Chart Recorders

Crystal Checkers

Decade Dividers

Decade Resistors

Differential Voltmeters

Digital Probes

Digital Voltmeters

Doppler Simulators

Frequency Counters

Frequency Meters

Integrating Digital Voltmeters

Load Simulators

APPENDIX F: REGIONS AND ASSOCIATED AFBs USED IN TRAVEL COSTING

<u>Region</u>	<u>Base Descriptor</u>
1 Northwest	Fairchild Malmstrom McChord Mountain Home
2 Southwest	Beale Castle Davis-Monthan Edwards George Hill Indian Springs Los Angeles Air Force Station Luke March Mather McClellan Nellis Norton Travis Vandenberg Williams
3 North Central	Ellsworth Grand Forks Minot Offutt
4 Mid Central	Francis E. Warren Lowry McConnell Peterson Whiteman
5 South Central	Altus Barksdale Bergstrom Blytheville Brooks Cannon Carswell Dyess England Goodfellow Holloman Kelly Kirtland

<u>Region</u>	<u>Base Descriptor</u>
5 South Central (continued)	Lackland Laughlin Little Rock Randolph Reese Sheppard Tinker Vance
6 New England	Griffiss Hanscom Loring Pease Plattsburgh
7 Mid Atlantic	Andrews Bolling Dover HQ USAF Langley McGuire
8 Midwest	Chanute Grissom K.I. Sawyer Scott Wright-Patterson Wurtsmith
9 Southeast	Arnold Charleston Columbus Eglin Gunter Homestead Hurlburt Field Keesler MacDill Maxwell Moody Myrtle Beach Patrick Pope Robins Seymour Johnson Shaw Tyndall

<u>Region</u>		<u>Base Descriptor</u>
10	Europe	Ankara Aviano Bitburg Camp New Amsterdam Hahn Hellenikon Hessisch-Oldendorf Incirlik Iraklion Izmir Lajes Lindsey RAF Alconbury RAF Bentwaters RAF Chicksands RAF Fairford RAF Lakenheath RAF Mildenhall RAF Upper Heyford RAF Woodbridge Ramstein Rhein-Main San Vito Sembach Spangdahlem Tempelhof Torrejon Zaragoza Zweibrucken
11	Pacific	Andersen Hickam Wheeler Clark Kadena Kunsan Kwangju Misawa Osan Taegu Yokota
12	Greenland/Iceland	Keflavik Sondrestrom Thule
13	Alaska	Eielson Elmendorf Shemya
14	Panama	Howard